(*NEW SERIES.*) No. 55.

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS

OF THE

GOVERNMENT OF INDIA

The Structure of Hæmatopota Pluvialis (Meigen)

BY

CAPTAIN F. W. CRAGG, M.D., I.M.S.

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA BY THE DIRECTOR-GENERAL, INDIAN MEDICAL SERVICE.

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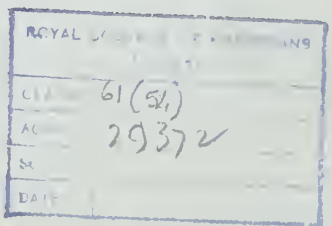

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BY

CAPTAIN F. W. CRAGG, M.D., I.M.S.

INTRODUCTION.

THE rapid advance which has taken place in recent years in our knowledge of the *hæmatozoa* has given a special interest to the study of the blood-sucking diptera, which, in so many cases, have been found to act as transmitting agents. A knowledge of the structure of the fly is essential in order to understand the various phases in the development of the parasite, and, as regards the pathogenic forms, the life history and habits of the transmitter have proved to be the dominant factor in any attempts to combat the disease in a rational manner.

Hæmatopota pluvialis is a fairly typical member of the Tabanidæ, a large and widely distributed family of flies, in which the blood-sucking habit is almost universal in the female sex. Up to the present, no member of the group has been proved to act as the host, in the strict biological sense, of a blood parasite, though there is little doubt that certain species can act as the transmitting agents of Surra and the allied diseases. Apart from this, the study of the group from the purely zoological point of view is of considerable interest. *Hæmatopota* shows, perhaps, the minimum amount of differentiation from the mandibulate type which is consistent with a blood-sucking habit, and thus affords an excellent opportunity for the study of the process of the adaptation of structure to function. As will appear later, this fly has many points of resemblance to both *Anopheles* (7) and to *Musca*, (6) and is, generally speaking, simpler in structure than either of these. Its relatively large size enables one to demonstrate such complicated processes as the mechanism of feeding or the articulation of the wing much more satisfactorily than could be done with smaller and less primitive insects.

A word is necessary with regard to the name Hæmatopota. Until recently this name was accepted without dispute, but recently an old paper by Meigen, of which only two copies are known to exist, has been unearthed, and from this it appears that, previous to the adoption of the name *Hæmatopota*, this genus was named by Meigen *Chrysozona* (8). A strict adherence to the established rules of zoological nomenclature would therefore necessitate the substitution of the name

* The substance of this paper was presented as a thesis for the degree of M.D. Edin.

Chrysozona for the well known one of *Hæmatopota*. The matter is still in dispute, and it remains to be seen whether the change of name will be universally accepted. The old name is used in this paper pending a settlement, since Mr. Austen is kind enough to inform me that he has not adopted the name *Chrysozona* for official use in the British Museum.

FIELD NOTES.

Under various local names, such as "cleg," "gadfly," "horse fly," the female *Hæmatopota pluvialis* is well known in most parts of the British Isles, and is much the commonest member of the Tabanidæ found in this country. It is on the wing from early June to the end of August or even later, and frequents damp pastures and country lanes, being seldom found far from water, or near houses. Its appearance depends to a remarkable extent on favourable conditions, *viz.*, abundance of sunshine and an absence of wind, and even in suitable weather it varies greatly in numbers in different years, from no ascertained cause.* Its flight is at times swift, but usually, when about to feed, it is rather deliberate and hovering, and is accompanied by a faint hum. So far as is definitely known, the fly is exclusively a blood-sucker, and attacks indifferently horses, cattle, or man, choosing those which are stationary or moving quietly about, and not selecting any particular part of the victim, the piercing organs being able to penetrate even the thickest parts of the skin.

The method of feeding, as observed on one's own hand, is as follows. After a short preliminary investigation, in which the labium appears to be used as a tactile organ, the piercing styles are inserted by a series of short sharp forward thrusts of the thorax, the labium being retracted and the labellæ everted behind the rest of the proboscis, and the maxilliary palps extended in front. As the wound is deepened the fly elevates itself on its hind legs, till the abdomen is tilted up at an angle of 45° or so, the forelegs being meanwhile extended in front of the proboscis, with their tibiæ held parallel to the surface. While in this position the abdomen gradually distends, and slight peristaltic movements can be seen in it. In a short time a clear fluid begins to exude at the anus, and this goes on as long as the insect feeds, the fluid becoming tinged with blood towards the end of the meal, and even, in some cases, appearing to consist of unaltered blood. Several times during the process the mouth parts are withdrawn a little and again thrust in; finally they are withdrawn by a few sharp jerks, and the fly, after resting a moment to clean its proboscis with its forelegs, flies away. A small drop of blood usually oozes from the puncture, and a faint ring of hyperæmia, with usually some slight irritation mark the site for a day or so. The pain caused by

* The larvæ of this fly live in damp mud along the banks of streams and ponds. A flood occurring at the breeding season would therefore materially reduce the numbers of the imagines in the following year.

the bite is usually trifling, less than that of a mosquito bite. Some individuals, however, appear to be remarkably sensitive, and suffer for days, even a week or longer, from local irritation and inflammation.

The fly takes about three minutes to obtain a full meal, and while feeding it is not readily disturbed; and the process can be watched on one's hand through a pocket lens.

The habit of defæcating while feeding, usual in blood-sucking insects, has an important bearing on the question of the normal parasites of the fly, for it is obvious that any encysted phases of such parasites which may be free in the hind gut at the time of feeding will be deposited on the skin of the host, and will be in a position to be taken up by another fly. In the case of the *Tabanidæ* it is easy to see how such parasites might be caught in the everted labellæ, and so find their way into the pharynx as the insect feeds. This species is not gregarious, except in the sense that large numbers may be found feeding in the same host, and they do not appear to collect in particular localities in the evening, as described by Hine (9) for certain American Tabanidæ. In view of their habit of defæcating on the skin of the host, it does not appear to be necessary to assume that parasites are transmitted from one fly to another, as described by Patton (10), by the uninfected fly inserting its proboscis into the fæces of an infected fly, in their evening resting-places.

The male of this species is extremely seldom met with,* even in localities in which the female is common enough to be a nuisance. During two months in a district where the females could be seen almost every day, only two males were caught, and both of these were obtained early in the season. The male is a flower feeder, and does not suck blood. A suggestion as to the cause of its remarkable scarcity will be made when considering the reproductive organs of the female.

METHODS.

The parts were studied by the dissection of fresh specimens, and by the preparation of serial sections. Dissections of the various organs, after fixation in sublimate alcohol, were stained in various ways, chiefly with borax carmine and Delafield's Hæmatoxylin, and mounted as permanent preparations. The chitinous parts were dissected after treatment with caustic soda solution for varying periods, with or without decolorization with chlorine gas. The proboscis, head, thorax, and abdomen were separately embedded and cut in serial sections by the combined paraffin and celloidin method, and the sections, though showing a good deal of shrinkage as a result of the long time required for complete penetration of the fluids, were very useful in checking the result of dissection.

* *Vide* Bruce, Report of Sleeping Sickness Commission. Proc. Roy. Series. B, Vol. 33, No. B 565.

For the study of the mouth parts and of the complicated structures at the base of the skull, it was found convenient to embed the whole head, after prolonged treatment with a weak solution of caustic soda, in paraffin, and then to cut away by hand the portions not required. The paraffin was then dissolved off in clove oil, and the preparation mounted, with or without further dissection, in a hollow slide. Similar preparations were made of the sides and lower part of the thorax, and were found to be much more satisfactory than simple dissections.

The separate organs were fixed and preserved, after dissection, in Bles' fluid,* and subsequently embedded and cut in sections. This is a most convenient method of fixation when one is away from a laboratory, and the tissues, even after preservation for several months in the fluid, stain quite well.

In the description of the parts, the terms superior, anterior, etc., are used in their strict anatomical sense, with reference to the fly in a resting position on a horizontal surface. It is important to note this in the description of the head, since the mouth parts are almost perpendicular to the long axis of the body. The term proboscis is used to include all the protruding mouth parts.

EXTERNAL ANATOMY.

I.—The Head.

(*a*) External Appearance. (Plate III, Fig. 10.)

The head has the shape of a somewhat flattened dome ; it is rather more than twice as broad as it is long, and is a little broader than the thorax. The antennæ project forwards from the apex of the dome, and the proboscis hangs downwards from the lower surface. The base of the dome, forming the posterior surface of the head, is concave to correspond with the convexity of the prothorax. The outer thirds of the head, as seen from the front, are occupied by the large compound eyes, the space between them being filled in by a square-shaped piece of the epicranium. This piece is light fawn coloured, is covered with fine hairs, and has on it three pigment spots, two large and anterior, the third, much smaller, mesial and behind the other two. There are no ocelli. The posterior border of this epicranial plate, constituting the vertex of the head, is hollowed out into a shallow groove, which is continued on to the posterior surface of the head. Bounding this groove there are two ill-defined sutures, which pass from the posterior and internal angles of the eyes to the posterior surface of the head, converging towards the occipital foramen.

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* Formalin . . . 7 parts.
Alcohol, 70 per cent. . 90 „
Glacial Acetic Acid . . 3 „

In front of the above piece, at the apex of the dome, there is a shining black transverse band, elevated somewhat from the surface, which bears the antennæ. This band occupies almost the entire space between the eyes, and is separated from the epicranial plate behind and the clypeus below by definite sutures.

The *Clypeus* is an oblong plate, rather narrower above than below, which stretches from the antennal plate to the labrum. It is light fawn in colour, and is speckled with fine pigment spots, and covered with fine hairs. There are two pigment patches, resembling those on the superior epicranial plate, in its upper half. The anterior openings of the intracranial tunnels, to be subsequently described, lie in the lower third of the sutures bounding the clypeus in each side. The *Genæ*, as seen from the front, fill in the triangular areas between the eyes and the clypeus ; there is no suture intervening between them and the posterior surface of the head. They resemble the clypeus in colouring, and are dotted over, especially in the upper parts, with coarse pigment spots, and have a dense coating of long fine hairs, which project inwards to merge with those on the maxillary palps.

The posterior surface of the head is vertical, and slightly concave. The occipital foramen is situated near its lower border ; in front of this opening, there is on each side a small stirrup-shaped aperture, the posterior end of the intracranial tunnel.

The *Eyes* are conspicuous for their large size and beautiful colouring. The ground colour is a bright iridescent greenish gold, which, unfortunately, fades rapidly on the death of the insect. Running transversely across the eye there are five irregular bands of reddish brown ; these markings are retained, though somewhat faintly, in specimens preserved in alcohol. The facets of the eye are hexagonal with rounded angles and are of approximately equal size and shape throughout. There are a few minute hairs scattered over the surface.

The *Antennæ* (Plate III, Fig. 12) are situated on the antennal plate already noted. They consist of three joints, the distal end being about as long as the first and second together. The first joint is cylindrical, the second short and round. The third joint is ringed, having upon it three constrictions, which divide it into four segments. The first of these segments resembles the basal joint, but is more slender ; the second and third segments are equal, and short and round ; the terminal segment, which is rounded at its apex, is a little longer than the two preceding ones together. The first joint is rather sparsely covered with large, black, forwardly directed bristles ; the second joint has a set of similar bristles arranged in a whorl, and a few similar but smaller hairs are arranged about the constrictions on the distal joints, and in a loose whorl round the middle of its first segment.

(*b*) The Mouth Parts.

These consist of two paired organs, the *mandibles* and *maxillæ*, three single mesial styles, the *labrum*, *epipharynx*, and *hypopharynx*, and a large fleshy *labium*, in the groove on the anterior surface of which the piercing styles lie when at rest.

The *Mandibles* (Plate II, Fig. 9) are the most powerful of the piercing organs. The blade has the shape of a short, broad, pointed and slightly recurved sabre. The internal edge is armed in its distal half with a regular row of extremely minute serrations ; the proximal half of the edge is extremely fine and attenuated. The external edge is sharp only at the distal end. Proximally it broadens out, so that the blade becomes triangular in cross section, and two stout strands of chitin are developed along its margin, one of which crosses the surface of the blade, while the other runs directly upwards to the base of the mandible. These two strands are produced into two cornua, and the horseshoe-shaped arch between them is further strengthened by thick fibres. The external horn articulates with a projecting angle of the epicranium, the joint corresponding to the ginglymus of mandibulate insects. The internal horn is free, and lies on the membrane which completes the base of the skull in this region.

The *Maxillæ* (Plate II, Figs. 1 and 2) are remarkable in that the several parts of a primitive first maxilla, *viz.*, cardo, stipes, galea, lacinia and palpus, can be readily recognised.

The *Galea*, or blade, is a stout slip of chitin, the same length as the mandible. It is quadrilateral in section at its tip, but becomes flattened proximally, and at the base merges with the stipes, the yellow chitin characteristic of the piercing parts giving place to that of the ordinary skeletal type. The tip is armed with a covering of minute flat teeth or rasps, arranged in a somewhat imbricate manner, with their points projecting upwards. These teeth are continued along the edge of the blade as it becomes flattened, for about half its length on the inner side, not quite so far on the outer side. The blade is strengthened by the development of two strands of chitin, one of which, the larger, runs down the middle, and merges with the stipes, while the other, lying nearer the internal edge, is produced into the lacinia.

The *Maxillary Palp*, which rises from the outer side of the stipes some distance above the base of the galea, is two-jointed and antenniform. The first joint is short and cylindrical, the second conical and pointed, and much larger than the first. Both joints have a dense covering of long fine hairs, many of which are pigmented. The two palpi turn inwards and forwards from their origin, and so come to lie in contact with one another, in front of the basal piece of the labium, in such a way as to close in the groove in which the piercing organs lie when at rest.

The *Lacinia* is a short peg-shaped projection arising from the inner edge of the galea at its base. The two laciniæ project inwards opposite to one another at the level of the articulation of the mandible, and assist in supporting the membrane at the base of the skull.

The *Stipes*, which is directly continuous with the galea, is a much convoluted piece, lying behind the pharynx and extending upwards to a point about midway between the base of the mandible and the occipital foramen. It may be described as consisting of a vertical rod, flattened transversely, and bent outwards in its lower third, then inwards and again outwards at its upper end, where it articulates with the cardo. The lower third of the inner edge is turned forwards, and there is a blunt projecting spur on the middle of the outer edge. On the posterior surface of this plate, at its lower end, there is a well-marked ridge, into which the central strand of the galea runs, and to which the palp is attached.

The *Cardo* is a small wedge-shaped piece which connects the maxilla with the cranial wall. Its base articulates with the stipes, while its apex, which is turned outwards, rests in a notch in the thickened edge of the epicranium bounding the central space. (Plate III, Fig. 13.) The cardo lies behind the base of the intracranial tunnel, and is crossed by the attachment of this tube to a curved rod, to be subsequently described.

The *Labrum* (Plate II, Fig. 7) is a thin spatulate slip, which is fused, except for a short interval at its upper end, with the epipharynx. When the two are separated by dissection, it is seen that the labrum does not extend quite to the tip of the epipharynx and that its margins are extremely thin and ill-defined. It is attached to the clypeus by a narrow Y shaped slip of brown chitin.

The *Epipharynx* (Plate II, Fig. 7) is shaped like a broad two-edged sword. It is directly continuous at its base with the anterior of the two chitinous plates which form the pharynx, and has on its posterior surface a deep groove, the edges of which are incurved so as to include about four-fifths of a circle. This groove, when opposed to the hypopharynx, forms the canal up which blood is sucked. The tip of the epipharynx is blunt, and is occupied by three small tubercles, two of which are lateral and anterior, while the third is situated at the extreme tip. These tubercles consist of a large number of small blunt teeth, arranged in rows in a radiating manner. The edges of the epipharynx are fine and sharp, and show an oblique striation, internal to the edges, and there is on each side a strong supporting band of fibres running in a longitudinal direction, and internal to this, between it and the canal, there is a small amount of cellular tissue, well seen in cross section. (Plate II, Fig. 3.)

The *Hypopharynx* (Plate II, Fig. 8) resembles the epipharynx in shape, but is more slender, and tapers more towards its point. It is pierced throughout its

length by the salivary duct, which opens at its tip. The edges of the blade contract sharply at the base, where the duct opens into the salivary reservoir. The hypopharynx consists of two laminæ, which are readily separated in dissection. The anterior and larger of these is continuous with the posterior plate of the pharynx and with the salivary reservoir, while the posterior lamina is attached to the cornua of the labium.

The *Labium* (Plate II, Figs. 4 and 6) has a somewhat complicated structure. It is partly composed of thin chitinous plates, and partly of a flexible membrane, which connects the chitinous parts so as to enclose a tubular space, in which there are contained certain muscles and cellular structures. The distal half of the labium is divided into two labellæ, on the opposing surfaces of which the arthrodial membrane is replaced by a pseudo-tracheal membrane, similar to that of the house fly. The loose connection of the chitinous plates, by means of the membrane, permits of a considerable degree of movement of the labellæ on the labium and on one another. The anterior surface of the labium is deeply grooved for the reception of the piercing mouth parts. The main support of the upper half of the labium is a large shield-like plate, aptly termed by Meinert the *scutum*. This piece is concave forwards, and forms the posterior and lateral walls of the upper half of the organ. The narrow upper end is produced into a pair of cornua, which lie behind the salivary receptacle and are attached to the non-chitinized membrane, which, as will be seen subsequently, completes the base of the skull. The arched upper border of the scutum has, on each side, a row of six long black macro chaetæ. In the middle of this border a pair of short, pointed processes, called by Meinert the *cardines*, project downwards.

In front of the scutum, and of course, separated from it by the muscles lying between the membraneous folds, there is a somewhat ill-defined chitinous plate which forms the floor of the groove in which the piercing parts lie. This plate is also concave forwards, though its contour differs considerably at different levels. The membrane which completes the wall of the labium in this region is attached to the sides of this trough-like piece and to the corresponding sides of the scutum, and is folded forwards, to a degree varying in different preparations, over the groove in the anterior surface. In this way the membraneous wall of the labium together with the maxillary palps, which lie in front of the upper part of the labium, entirely conceal the rest of the mouth parts. Below the level of the scutum, and external to the cardines, there is on each side an oval plate, called by Meinert the *Stylus Extensoers labellæ*, and by Hansen the *Lamina articuli secundi labii*. On the internal surface of this plate there is a thick dentate ridge, which curves slightly inwards, so as to rest in the angle on the lower border of the scutum external to the cardo. The pointed lower end of the plate fits into a notch in the

chitinous framework of the labellæ, when the latter are brought parallel to the surface on which the insect rests.

The *Labellæ* are oval lobes, attached to one another behind, but diverging in front. They are set on the labium at an angle of about half a right angle, so that their long axis points upwards and backwards from the labium. Their outer surfaces are mainly membraneous, but are stiffened by the development, on each side, of two thin plates of chitin along the border. The upper one of these plates lies in the projecting posterior angles of the labella, and is square-shaped. Its lower side is produced into a narrow spur, which runs forward across the outer surface, and bears a row of six or seven short but stout black bristles. The anterior side of the plate is incurved below this spur, so as to form a notch for the reception of the "stylus." The lower plate is about twice the size of the upper, and lies in the long axis of the labella. Its upper and anterior sides are thickened and ridged for muscle attachment. Many short, stout, black hairs are scattered over the outer surfaces and posterior borders of the labellæ; they are especially numerous in the larger chitinous plate. No special sense organs have been found in connection with these setæ, although, from the manner in which the insect uses its labellæ, one would expect to find something analogous to the tactile organs in the proboscis of the house fly. The membrane attached to the scutum is produced downwards, and holds together the various chitinous plates described. It is continued for a short distance round the anterior and posterior borders of the labellæ, but is replaced, on their inner and opposing surfaces, by a *pseudo-tracheal membrane*. This membrane is clear, transparent, and apparently structureless. Its surface is traversed, on each side, by twenty-six deep grooves, which converge from the posterior border inwards, so that, accommodating themselves to the oval shape of the labellæ, the upper ones run downwards and inwards, the lower ones upwards and inwards, while the middle ones are directly transverse. These grooves lead to, but do not actually communicate with, a short but broader longitudinal groove which runs along the inner border of each labella. When examined under a high magnification, it is seen that these grooves are lined with, and presumably kept open by, a series of minute incomplete chitinous rings, set side by side, transversely to the axis of the groove. Each ring is about three-quarters of a circle, and each end of it is thickened into a little knob, so that the edge of the groove has a beaded appearance.

The *labellar muscles* arise from the scutum, and are inserted into the lower chitinous plates. They consist of three pairs of muscles, not definitely separated at their origin. The most posterior bundle runs directly downwards to the "stylus," that is, the oval plate lying external to the cardines. The other fibres are inserted into the upper and lower chitinous plates of the labellæ, some fibres

being traceable almost to the tip. Contraction of all these bundles together will retract the labellæ, while contraction of the anterior fibres only will bring the labellæ more parallel to the surface on which the fly is resting.

Two trachea enter the base of the labium. They expand at the region of the scutum into two comparatively large air sacs, from which the trachea can be traced downwards for a short distance. There is also a pair of small nerves, lying internal to the muscles.

Cellular Structures.—The membrane, and the chitinous plates developed in it, are lined throughout by an indefinite layer of small round cells. The anterior plate which forms the floor of the groove in which the piercing mouth parts lie is lined by a single layer of small regular cubical cells, which extend forward to the junction of the plate with the membrane. The pseudotracheal membrane is lined throughout by a single layer of similar, but larger, cubical cells. There are a few fat cells scattered about the interstices of the organ.

The space between the pseudotracheal membrane and the outer wall of the labella is almost entirely filled up by a large mass of cells, which probably represent a labial salivary gland. (Plate II, Figs. 3 and 4.) These cells are remarkably large, averaging about 40μ in their long axis. They are oval or pear-shaped and are arranged with their narrow ends pointing towards the pseudotracheal membrane, the innermost ones lying in contact with the cubical cells. The nucleus is round or oval, and is situated at the broad end of the cell. The chromatin appears to be separated into a large number of small rods, mainly aggregated about the periphery. In many cells there is a second nucleus, usually very small, situated at the narrow end of the cell. The protoplasm contains many fine granules, and is, in a small proportion of the cells, vacuolated. In each cell there is a crescentic or sickle-shaped area, near the nucleus, where the protoplasm is non-granular and does not stain well, being only faintly tinged by cosin. In a few cells a distinct vacuole can be made out inside this area.

It is evident from its structure that the labium exercises other functions as well as the obvious one of protecting the other mouth parts. The pseudotracheæ differ in no essential particular from those of the house fly, except that there is no direct communication between them and the alimentary canal. This is not, however essential. If fluid is drawn inwards along the pseudotracheæ by capillary attraction, it will come to lie in contact with the hypopharynx and epipharynx, the distal ends of which lie between the two internal longitudinal pseudotracheæ. It may then, either by capillary attraction or by contraction of the pharyngeal muscles, be drawn into the pharynx. I have never myself seen *Hæmatopota* drink, but it appears to be generally agreed that Tabanidæ do so. Austen (13), quoting Pontschinsky, states that in Russia horse flies are destroyed in large numbers by pouring petroleum on the pools to which they resort.

There are no ducts to be made out in connection with the labial gland cells. Their secretion is probably exuded by means of the cubical cells lining the pseudo-tracheal membrane.

(c) The Intracranial Tunnels.

These remarkable structures lie in the lower part of the head. Each consist of a stout hollow chitinous tube, which opens on to the anterior and posterior surfaces in the positions already indicated in the description of the external characters. The two tubes lie in a horizontal plane, and converge somewhat towards one another from before backwards. The main portion of the tube is cylindrical and is narrowest about its middle. The anterior end is funnel-shaped, and has a wide attachment to the epicranium in the region of the clypeus and gena. The posterior end, which lies in front of the cardo of the maxilla, is more irregular and is produced into three tubercles. One of these projects inwards, while the others are firmly attached by strands of chitin to the thickened lateral edge of the epicranium, and to the curved rod which extends from the region of the orifice to the occipital foramen.

From the upper surface of each of these tubes there arises a thin *trabecular membrane*. This is triangular in shape, and is attached in front to the epicranium at the junction of the clypeus with the gena, extending as high as the antennal socket. The free upper margins of the two trabecular plates separate off a median compartment in this region of the head, in which the pharynx and the pharyngeal dilator muscles are contained.

These intracranial tunnels resemble those described in Chironomus (14) and in Anopheles (7). They are of the nature of supporting buttresses, and the fact that they are hollow has probably no more singificance than that, weight for weight, a hollow cylinder is stronger than a solid rod. Their special functions will be discussed in relation to the mechanism of feeding.

(d) The Structure of the Base of the Skull. (Plate III, Fig. 13.)

The chitin of the head capsule is deficient in a space extending from the occipital foramen to the bases of the mandibles, this area being filled in by a flexible non-chitinized membrane. The space is bounded in front by the cornua of the mandibles and the lacinæ of the maxillæ, and laterally by the thickened edge of the epicranium, and by a specially developed curved rod. The central part of the space is occupied by the pharynx, on each side of which lie the stipes of the maxillæ.

The lateral curved rods, previously referred to, extend from the posterior orifices of the intracranial tunnels to the occipital foramen. They are flattened

and shaped like boomerangs. The lower end of each rod is produced into a tubercle which projects inwards into the central space, while the upper ends are produced inwards in front of the occipital ring, and are united by a few strands of fibres, so as to form the anterior boundary of the foramen. About the middle of each rod there is a constriction, and above this the rods are fused with the epicranium.

The upper and posterior border of the occipital foramen is formed by a thickened arched ridge, continuous with the posterior wall of the head capsule.

(*e*) The Homology of the Head.

It is of course somewhat difficult to assign the component parts of the head to their respective segments with precision from a study of the adult insect, and especially when, as in this case, few of the sutures marking the lines of fusion of the segments can be made out. The parts in *Hæmotopota*, however, represent a comparatively early stage in the adaptation to the suctorial habit, and by comparison with other insects of more elementary form it is possible to define the extent of the various somites with some degree of certainty. The detailed exposition of the present views on the segmentation of the insect head given in Berlese's recent work (15) is adhered to in the following description. Berlese regards the insect head as derived from six segments, the third of which is wanting in the adult stage, except in *Campodea*. The first somite is the preoral one, and bears the eyes. The labrum and clypeus belong to it. The second segment bears the antennæ, and is well demarcated in this insect as the elevated antennal plate. The sternite of this segment is represented by the anterior parts of the intracranial tunnels and trabecular plates. The fourth segment bears the mandibles. Its tergite lies behind the antennal plate and extends between the eyes to the vertex. The sternite is represented by the genæ, the posterior border, and an indefinite area of the posterior surface of the head; its extent may be inferred from the area of attachment of the mandibular muscles. The mandible itself shows the least possible differentiation from the mandibulate type which is consistent with a blood-sucking habit. It is articulated to the gena, and, as will be seen later, the arrangement of its muscles indicates that it is capable of a relatively wide range of movement. Comparing it with *Blatta* and *Anopheles*, it illustrates very well the process of adaptation to function. The fifth segment bears the maxillæ. Its tergite occupies the lateral areas in the posterior surface of the skull, external to the sutures; the sternite is represented by the bases of the intracranial tunnels. The primitive form of the maxilla has already been discussed. The tergite and sternite of the sixth segment are not separated. The tergite occupies the median area of the posterior surface of the head, between the

sutures, and encloses the occipital ring above. The sternite has undergone considerable modification in the development of the membraneous area at the floor of the skull. The palatal membrane, representing the gular region of other insects, and the cornua and scutum of the labium, representing the submentum and mentum, belong to the sixth sternite. The cardines of Meinert and the stylus may represent the cardines and stipes of a primitive second maxilla.

II.—The Thorax. (Plate V, Fig. 19.)

The head is attached to the thorax by a short neck, which, on account of the concavity of the posterior surface of the head, is not easily seen on the living insect. There are no cervical sclerites.

The Thorax, as seen from above, is ovoid in shape, the pointed scutellum projecting backwards above the first abdominal segment. It is rather narrower than the head, and is continuous with the abdomen without any " waist." It is dark tawny brown in colour, with a dorsal median light stripe, continuous with that on the abdomen, and two lateral stripes, the inner of which extends only through the anterior half. It is covered throughout with short downy hairs, which are aggregated into little tufts on certain of the sclerites, especially about the neck and sides.

There is no differentiation of the thorax into three regions, and the separate parts can only be satisfactorily studied by dissection.

(*a*) The Prothorax.

The sclerites of the prothorax close in the convex anterior end of the thorax, and can only be satisfactorily seen after removal of the head. There are seven paired and two unpaired sclerites.

On the ventral aspect, immediately behind the thoracic inlet, there are three pairs of sclerites which belong properly to the neck. These " jugulares " lie in a loose anthrodial membrane, and are not united directly to one another in the middle line. The first, which is the largest, is dome-shaped, and bears a tuft of dense hairs. It is free in the anthrodial membrane. The second piece is a transverse oblong slip, attached externally to the epimeron ; it bears no hairs and is not recognizable in the external surface of the thorax. The third jugular resembles the second, except that it bears hairs, and is attached also to the episternum. It lies in front of the articulation of the foreleg. The looseness of the thoracic wall in this region permits of considerable distension during the act of feeding.

The remaining sclerites are readily homologized with those of a primitive thoracic segment. The ventral sclerite is divided into a pair of *Presterna*, a

Sternum, and a *Sternellum*. The *Presterna* lie on the inner sides of the spaces in which the forelegs are articulated, and behind the jugulares. They are quadrilateral in shape, and are firmly united by their inner borders, from which a thick ridge projects upwards into the thoracic cavity. Their anterior borders form a continuous thickened arch, to which the arthrodial membrane is attached.

The *Sternum* is a small semicircular plate, which is wedged in between and behind the presterna, which project backwards on each side of it. The sternellum is heart-shaped, and is inset between the diverging inner borders of the sterna of the meso-thorax. The sternum and sternellum do not bear hairs, and are easily recognizable on the external surface of the thorax.

The *Episternum* lies external to the articulation of the foreleg, and is firmly attached to the meso-thorax. The *Epimeron* lies in front of the episternum, and is closely adherent to it and to the præsternum. Both lateral sclerites are rounded and convex, and are conspicuous on the external surface, having dense tufts of hairs. The *Pronotum* is represented by two small convexities on the outer edges of the prescutum ; they are continuous with the epimera.

Passing between the ventral and lateral sclerites there is a somewhat complex arrangement of fibrous bands, representing an antefurca, which serves both to compensate for the laxity of the thoracic wall in the region of the jugulares, and to provide for muscle attachments. (Plate IV, Fig. 14.) It consists of two parts, arising from the sternum and sternellum respectively. The anterior fibres arise from the arched border of the sternum, from the posterior fourth of the median ridge between the presterna, and from a thick transverse strand which separates the sternum from the sternellum. The fibres are collected into a broad-arched transverse band, which, as it runs outwards, contracts to form a stout round cord. The posterior fibres arise from the thickened and ridged lateral borders of the sternellum, and run outwards and forwards. All these fibres run towards the junction of the epimeron and episternum, and are mainly attached to the recurved anterior margin by the latter sclerite. They form a strong supporting buttress for this part of the thorax.

(*b*) The Mesothorax.

This constitutes the main part of the thorax. The tergite, which occupies the whole dorsal surface of the thorax, is separated into a *Prescutum*, *Scutum*, and *Scutellum*. The two former pieces together make up the greater part of the tergite, and the separation between them is only indicated by a short lateral furrow anterior to the wing base. The *Scutellum* is a stout triangular piece, with rounded margins, which overlaps the first abdominal segment, and conceals the metathorax from above.

The *Sternum* is divided into two quadrilateral plates, which are united along the middle line at an angle, thus giving the thorax a keeled appearance. The *Episternum* lies directly above the sternum, and resembles it in shape. Both these sclerites are united to the adjacent plates, and to one another, the lines of junction being marked on the internal surface by prominent ridges. The *Epimeron* is a narrow and irregular vertical plate, extending from the wing base to the middle line below. The upper third of its anterior margin is separated a short distance from the episternum, the interval being filled in by arthrodial membrane, on which the anterior series of wing sclerites lies. The middle third of the margin is united with the mesosternum, and below this the two diverge, leaving an interval in which there lies a conical coxal plate, with which the middle leg articulates. The upper third of the epimeron is concealed, from within, by the wing sclerites. Its posterior margin is ill-defined, and merges into the membrane to which the squama is attached. The middle third is produced backwards, forming a dome-shaped expansion, which lies below the squama, and which gives origin to the mesophragma. The posterior thoracic spiracle lies in a membraneous interval below this expansion. The lower third of the epimerion tapers to a blunt point; it is partially fused with the metathorax.

The *Mesophragma* is a funnel-shaped expansion, which projects backwards and inwards into the thorax, materially diminishing the size of the thoracic outlet. It arises from the upper and lower borders of the dome-shaped expansion on the epimeron. From these borders thin sheets of chitin are reflected upwards and downwards into the cavity of the thorax, those from the two sides meeting above and below, so as to form a sort of inner chamber in the thorax. This funnel, which is more extensive above than below, extends backwards as far as the first abdominal segment, and contains all the organs passing from the thorax to the abdomen. In cross sections of the posterior end of the thorax it appears as an isolated ring of chitin, giving attachment to the longitudinal muscles of the thorax. Between the scutum and prescutum above, and the episternum below, there is a narrow longitudinal interval, filled in by arthrodial membrane. This is prolonged downwards to separate the episternum from the epimeron. The anterior thoracic spiracle lies at the anterior end of this space.

(*c*) The Sclerites of the Wing Base.

These are arranged in two sets. The anterior set consists of three wedge-shaped rods, which are attached to one another and to the adjacent sclerites by their expanded upper ends, their pointed apices hanging down internal to the episternum and the arthrodial membrane. The largest rod is situated between and internal to the other two. The pointed anterior angle of its base is attached

to the prescutum, near the lateral furrow separating it from the scutum, by a strong band of fibres. The anterior rod is attached at its base to the largest rod. The posterior wedge is shorter and stouter than the others, and is attached by the anterior angle of its base to the first rod, and by its apex to the anterior margin of the epimeron, by stout cords.

This set of sclerites, by virtue of the elasticity of the fibrous cords connecting them with the dorsal and lateral walls of the thorax, and by means of the muscles attached to them, will antagonise the longitudinal muscles, by reducing the vertical diameter of the thorax.

The posterior sclerites are directly associated with the wing, and form a series of levers by which the wing can be folded and unfolded. They are five in number, and are of too irregular a shape to be accurately described. Their arrangement is indicated somewhat diagramatically in the figure. (Plate V, Fig. 19.) The costal vein terminates in a round knob, produced downwards into a fibrous cord. The radial vein terminates in a very complex sclerite, which lies upon the upper end of the epimeron, and receives, in its anterior border, the fibres from the costal vein. Co-relation between the two important veins of the wing is thus secured. The posterior margin of the wing terminates in a conical sclerite, which lies behind the radial sclerite but is not connected with it. The squama is closely connected with a curved rod lying in the membrane at its base, and this rod is attached above to the base of the sclerite which terminates the posterior border of the wing. Below these four rods there lies a Y shaped rod, which is the governing part of the mechanism. This rod is horizontal, the fork of the Y being anterior. The lower limb of the fork is received into a little pit in the epimeron ; the upper limb is bifid, and interlocks with the bifid lower end of the radial sclerite. The posterior long limb of the Y is attached to the curved rod at the base of the squama.

If one bears in mind that when the wings are folded on the abdomen the squamæ are folded on the wings, the mode of action of these levers becomes obvious. When the long arm of the Y is pushed up, the radius, and with it the costa, are pressed backwards, while the squama is pushed in the reverse direction.

The *Medi-furca* is composed of two large lateral expansions, set on a Y shaped stalk. It lies in the angle between the mesosterna, and is attached, somewhat loosely, to the posterior part of the ridge between them. These lateral expansions are formed from two plates of chitin, lying one above the other. The plates are roughly oblong in shape, but with their external anterior angles produced forwards ; they are united along their inner and anterior borders, but diverge from one another behind, and are separated posteriorly by a small vertical plate, so that they enclose a boat-shaped cavity. Behind this expansion there is another about

one-fourth the size, and formed in the same way from two triangular plates. These are attached in front to the plate representing the stern of the boat, and converge to meet one another behind. The fork of the stalk is much thickened and ridged to resist the strain which falls on it during the contraction of the transversely acting muscles attached to the apodeme.

(*d*) The Metathorax.

The metathorax is much reduced in size, and the separate segments are difficult to recognise. The mesophragma passes backwards through the metathorax.

The *Meta-notum* is a narrow thickened arched ridge, which lies beneath the scutellum, where it articulates with the tergite of the first abdominal segment. The *pleural sclerite* is undivided, and forms a narrow plate extending from the insertion of the halter to the middle line. It is attached to the meta-notum above and behind, and to the epimerion of the mesothorax in front. The *meta-sternum* is a small oval plate, fused with the pleural sclerites. It bears the post-furca, and its posterior borders are deeply excavated for the reception of the coxæ of the hind legs.

The *Post-furca* lies on the metasternum, anterior to the coxæ. It consists of a pair of pointed wing-like expansions, united with one another and supported by stout ribs. It is attached to the median ridge between the two lateral halves of the metasternum. Each expansion is supported by a Y shaped rib, the inner limb of which runs to the extreme tip of the apodeme. These ribs converge inwards and backwards, and those of the two sides are connected by a sheet of chitin. They do not meet posteriorly, but diverge again, and terminate in a pair of stout-hooked processes, which lie between the coxæ, and are closely connected with the median ridge on the metasternum.

(*e*) The Wings.

The wings, when in the resting position, extend a little beyond the tip of the abdomen, and are held in a tectile manner. Their general shape is indicated in the figure. (Plate I.) They are light brown in colour, and are mottled with patches of a lighter tint. The inner half of the posterior border of the wing is indented, so that a large *anal lobe*, a smaller *alula*, and a still smaller *antisquama*, can be distinguished. The *squama* is specially differentiated, and is relatively rather large and conspicuous. It lies in a plane almost at right angles to the wing when the latter is moderately extended, and, as the wing is folded backwards, the squama is folded on it so that it lies in contact with the antisquama. The special mechanism by which this is accomplished has already been described. The squama is some-

what thicker than the rest of the wing, and has a thickened margin, which bears a fringe of fine hairs.

The distribution of the wing veins is sufficiently indicated in the text figure. The terminology employed is that of Conistock and Needham (16). The *Costa* extends to the tip of the wing and is continuous with the thickened posterior border. It bears four rows of small spines, which extend all round the wing. The *Radial vein* divides into four branches, of which the second represents the fused second and

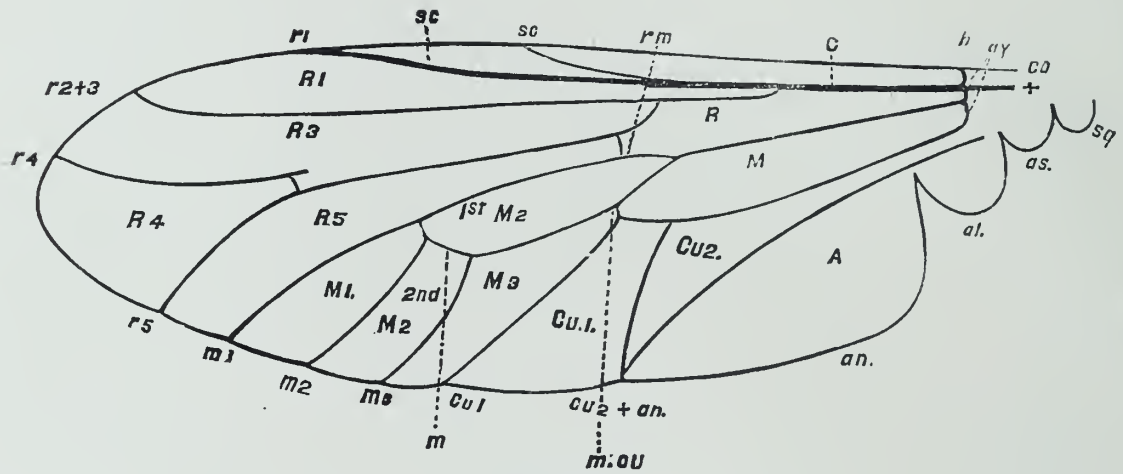

FIGURE I.

Venation of Wing.

co., costa; sc., subcosta. r. 1, 2, 3, 4, the four divisions of the radial vein; m. 1, 2, 3, the three divisions of the median vein; cu. 1, 2, the two divisions of the cubital-vein: an., the anal vein; h., the humeral cross-vein; ay., the axillary crossvein; rm., the radial median cross-vein; mcu., the median cubital crossvein; R, R1, etc., the radial cells; M, M1, the median cells; Cu, 1 and 2, the cubital cells; A., the anal cell; an., the anal lobe; al., the alula; as., the antisquama; sq., the squama.

third radial veins. The first radial vein, the stoutest in the wing, bears a single row of small spines. At its termination there is a small oval area of dark pigmentation, the "stigma." The division between the fourth and fifth radial veins is peculiar. The fourth vein turns forwards and then outwards from its origin, and from the angle so produced a stout spur projects inwards in line with the vein. At first sight it appears as if an adventitious cross vein had been developed, but a comparison of other *Tabanidæ* indicates that an obtuse angle is by no means uncommon at this junction. The peculiarity is the projecting spur.

(*f*) The Legs.

The legs are composed of five joints, as in other Diptera. The joints differ somewhat in the three legs. The coxa of the foreleg is long and cylindrical, and articulates with the thorax at a comparatively wide membraneous interval external to the presternum. The femur resembles the coxa, but is longer, and is covered with stout black setæ. The tibia is shorter and stouter than those of the other legs, and is covered with setæ. The coxa of the middle legs is much reduced in size; it articulates with the coxal plate which lies behind the mesosternum. The femur resembles that of the foreleg, except that the setæ are restricted to a small area just above the lower end. The tibia of this leg has two stout conical spines at its lower end. The coxæ of the hind legs are broad and oval, and lie almost in contact with one another, on the metasternum. The femur and tibia resemble that of the middle leg, except that the hind tibia does not bear spines. The metatarsus is the same in the three legs. There are five joints, the first of which is much larger than the rest. The next three joints are short and conical. The terminal joint bears two large symmetrical curved claws, and three pulvilli with glandular hairs.

The fore tibia is coloured yellow in its proximal half; the mid and hind tibia are yellow throughout, except at the lower end, and in small areas about the middle and the upper end.

(*g*) The Halters.

These are situated on the anterior edge of the metathorax, just behind the posterior spiracles. Each consist of a somewhat flattened ovoid knob, borne on a slender stalk, which terminates in an expanded base. The upper and lower surfaces of the halters are pigmented, and are covered by extremely fine hairs. The proximal expanded end of the stalk, and a small elevated cushion lying behind it, have on them a large number of minute shallow pits, on the margins of which there are a few small hairs.

III.—The Abdomen.

The abdomen is the same breadth as the thorax, and is about twice as long. It consists of seven visible segments, which decrease in width from before backwards, so that the last is about two-thirds the breadth of the first. The posterior segments are flattened from above downwards. The coloration resembles that of the thorax. The median light stripe is continued down the abdomen, and in addition there is on each segment a round spot on each side, and a narrow area on the posterior margin, of the same fawn colour. The whole abdomen has a scanty covering of downy hairs, and there is a small fringe of short stout setæ in the posterior border of the last segment. A pair of small oval anal lobes projects from under cover of the last segment.

The pleural membrane which unites the tergites and sternites, and which bear the spiracles, is capable of considerable distension, and is conspicuous in a recently fed insect.

Under cover of the seventh segment there are several small sclerites, which, with the anal lobes, may be taken to represent four reduced segments. Dorsally there is a plate resembling the seventh tergite, but about one-fourth the size ; behind this there are two pairs of small pieces, and the two anal lobes. On the ventral aspect the several pieces are fused into one, which is roughly square-shaped, with the posterior half of its lateral borders expanded. These sclerites are situated in an arthrodial membrane, and when they are drawn out, it is seen that the anterior margin of the first piece is attached to the posterior margin of the seventh segment, so that they form a continuous but retracted part of the abdominal wall. The arrangement probably represents, and functions as, an ovipositor. (Plate VII, Figs. 29 and 30.)

INTERNAL STRUCTURE.

I.—The Alimentary Canal.

This consists of the following parts :—

Pharynx.*
Œsophagus, with its diverticulum.
Proventriculus.
Mid-gut.
Hind-gut, divisible into—
    Ileum, with the Malpighan tubes.
    Colon.
    Rectum, with its papillæ.

The *Pharynx* is the most important part of the sucking apparatus of this insect. It consists of two oblong vertical chitinous plates, the anterior of which is continuous with the epipharynx, the posterior with the hypopharynx. These plates are concave forwards, and are closely apposed to one another in a state of rest ; they are united to one another by their lateral borders, and the pouch so formed opens below into the canal between the epipharynx and hypopharynx, and above into the first part of the œsophagus. The upper lateral angles of the pharynx are produced into two long cornua, which project upwards, and slightly forwards, into the cranial cavity. The pharynx lies on the palatal membrane, in front of and internal to the stipes of the maxilla. (Plate III, Fig. 13.)

* The nomenclature of Meinert is followed here. The first part of the œsophagus corresponds to the pharynx of the mosquito.

The *Œsophagus* consists of two parts, differing in structure and in function. The first part is accessory to the pharynx, and might perhaps be more correctly described as part of it, since it plays an important part in the mechanism of feeding (17).

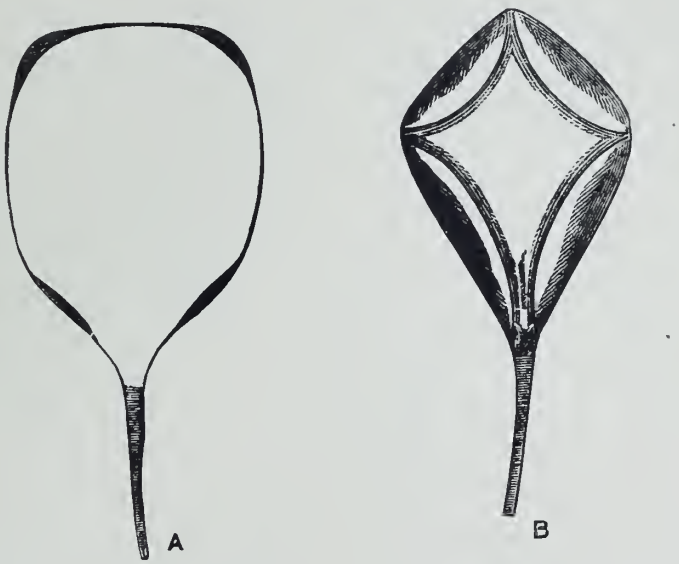

Figure 2.—The Chitinous plate of the œsophagus. A. When the pouch is dilated. B. When empty.

It is a dilatable chamber, situated between the cornua of the pharynx, and lying in a horizontal plane, that is, at right angles to the pharynx and proboscis. The superior and lateral walls of this pouch are formed by a quadrilateral plate of chitin. This plate is concave downwards, and its four angles are turned downwards towards the pharynx, and are connected with it by a thin membrane which completes the chamber. This membrane is attached to the margins of the chitinous plate above, and to the cornua of the pharynx and to the upper margins of the two pharyngeal plates below. The second part of the œsophagus turns directly backwards from the posterior angle of the first part, through the brain, occipital foramen, and neck, into the thorax. It terminates just behind the thoracic inlet in a small dilatation, in the dorsal aspect of which there is an aperture, by which the œsophagus communicates with the proventriculus. The intracranial portion of the œsophagus has a thin semi-membraneous wall, but as it passes backwards the chitin thins, and is replaced by a layer of small round cells, set on a basement membrane.

The *œsophageal diverticulum* is a small bilobed sac, which lies in the second abdominal segment, to the left of the middle line. It is connected with the œsophagus by a fine duct, which arises from the posterior end of the terminal posterior dilatation of the œsophagus, and runs backwards beneath the proventriculus and between the salivary glands. The walls of the diverticulum are composed of deli-

cate interlacing fibrils, in the meshes of which there are many round cells. The duct has the same structure as the thoracic part of the œsophagus, with which it is directly continuous, the distinction between them being only marked by a narrowing of the lumen.

The œsophageal diverticulum is usually distended with gas. Sometimes it is found to contain blood, but it apparently does not function in the same way as the corresponding organs of the mosquito, since it is frequently found to be empty in specimens dissected immediately after feeding.

The *Proventriculus* extends throughout the thorax, lying between the lateral expansions of the medifurca and on the mesophragma, and terminates in the second segment of the abdomen by joining the mid-gut. Its anterior portion is broad, flat, and has a mammillated surface ; the posterior portion contracts to form a simple narrow tube. At its anterior end there is on each side a wide wing-like expansion, the prominent anterior angle of which is produced forwards and outwards into a small pointed tubercle. It should be noted that the proventriculus lies throughout on a higher level than the œsophagus and its direct continuation, the œsophageal diverticulum ; the opening into the œsophagus is on the ventral surface of the proventriculus, a little behind its anterior end. The mammillated appearance of the surface is produced by folds in the wall : these are arranged somewhat irregularly, but there are usually two rows of small elevations to each of the surfaces, and one row in each lateral margin. The lumen of the proventriculus is a transverse slit, which becomes rounded in the posterior portion. The wall of the proventriculus is composed of a layer of round or oval cells, attached to a stout basement membrane. These cells, however, have the power of forming a large amount of secretion, which is collected in the cells towards their free margins, and eventually extended into the lumen. The appearances seen on section consequently differ widely at the various stages of this process. When the secretion is fully formed but not yet thrown off, the cells are elongate, and are arranged in rather indefinite rows. The nuclei are round or oval, and stain deeply. The borders of the cells adjoining the lumen are converted into a structureless hyaline eosinophil mass, in which the distinction between adjacent cells is lost. This hyaline layer is carried into all the folds of the wall, and renders the mammillation of the surface more marked. At a later stage this secretion is thrown off, and the lumen is found to be filled with a coarse granular mass, which takes up the eosin stain only faintly. The cells are flattened, and their nuclei lie close to the basement membrane, with their long axes parallel to it. The surface of the proventriculus is then not so mammillated, the lumen is less flattened. At a still later stage the lumen is found to be empty, and the wall closely resembles that of the œsophagus, being composed of a simple layer of round cells, the inner ends of which project into the lumen. These

remarkable changes are related to the feeding of the fly, and one of the same nature as those described by Schaudinn (18) in the mosquito.

The *Mid-gut* is the chief digestive part of the alimentary canal and is the only part in which blood is found in a recently fed insect. It lies in the second and third segments of the abdomen ,and is embedded in a mass of fat body, to which, and to the adjacent coils of the Malpighian tubes, it is closely bound down by a rich supply of tracheæ. It is oval or pear-shaped, the narrow anterior end, which is generally a little dilated when the gut is full of blood, merging indefinitely with the proventriculus, while the posterior end is sharply demarcated from the rest of the gut by the insertion of the Malpighian tubes. The wall of the gut consists of a single layer of long cylindrical cells, arising from a thin basement membrane, and two thin layers of muscle fibres, the inner layer being circular, the outer layer longitudinal. The cells, with their basement membrane, are collected throughout the cavity into small villi, so that the mid-gut has a stellate appearance on cross section. The cells lying between the villi are typically columnar and are regularly arranged, while those on the sides of the villus are more elongate, their attached ends being compressed. The appearance of the protoplasm between the nucleus and the free border of the cell varies in different preparations. In some it is clear, hyaline, and eosinophil, while in others it is vacuolated, and the border of the cell is frayed out, the cells having discharged their secretion after the manner of goblet cells. The lumen of the gut often contains large numbers of degenerated free nuclei, evidence of the degeneration of the epithelium. There are many small round cells, by means of which the columnar layer is regenerated, lying between the attached ends of the cells ; these are most conspicuous when the large cells have discharged their secretion.

The *Hind-gut* commences at the origin of the Malpighian tubes and is continued backwards as a simple narrow tube. The first part, immediately behind the mid-gut, is somewhat dilated ; the succeeding narrow portion is bent upon itself, passing first from left to right, then to the left again, bending upwards. The gut then dilates to twice its previous diameter, and runs directly backwards to join the rectum. The wall consists of a single layer of short cubical cells, on a basement membrane, and a few scattered bands of circular and longitudinal muscle fibres. Although there is no difference in structure, the anterior narrow portion may for convenience be termed the Ileum, the dilated posterior portion the Colon. The dilated anterior portion of the Ileum, in a considerable proportion of cases, has been found distended by two or three large gregarine cysts. The Colon frequently contains many large reddish granules, the remains of blood.

The *Rectum* is separated from the colon by a slight constriction of the gut. It is pear-shaped, the narrow end opening beneath the anal plates. The structure

of the wall resembles that of the preceding portions of the hind-gut, except that the circular muscle fibres are more numerous. There are six rectal papillæ inset in the wall. They are small curved, wedge-shaped bodies, projecting into the lumen of the rectum, their apices being directed towards the anus. They are composed of a single layer of large cells arranged around a central lumen, down which there runs a small tracheal twig which enters the papilla from the outside.

The *Malpighian Tubes* are four in number. Each tube, when dissected out, is about the same length as the whole alimentary canal. They are arranged in complicated loops, chiefly in the posterior part of the abdomen, and are closely bound down to the other organs by tracheal twigs. A long loop passes forwards in each side of the mid-gut. The tube is of uniform diameter throughout, and tapers to a blunt point which lies near the rectum. In fresh dissections this end of the tube has an orange-red colour. The tube is composed of a single layer of large flattened cells, with large oval nuclei, which are folded round the lumen and cemented by their edges. They are inserted into small expanded evaginations of the gut, where the large flattened cells become replaced by small round cells.

The *Salivary Apparatus* consists of a pair of glands, a duct, and a reservoir. The glands lie in the thorax, extending to its junction with the abdomen. They lie beneath the proventriculus, and in either side of the duct of the œsophageal diverticulum. They are long, simple, and tubular, and dilate gradually from before backwards, the posterior portions being curved outwards. They are composed of a single layer of cubical cells, and a stout basement membrane. The lumen generally contains a mass of small granules. Towards their anterior ends the glands narrow, and the basement membrane is reinforced by a series of coarse, closely-set chitinous rings, while the cells become flattened. The two ducts which are thus formed unite just before entering the neck, and the common duct, lying below the nerve cord, runs to the salivary reservoir. This salivary reservoir is a small chitinous pouch situated on the lower half of the posterior surface of the pharynx ; it opens below into the duct in the hypopharynx.

II.—The Respiratory System. (Plate V, Fig. 20.)

The *Head.*—Two small tracheæ from the anterior thoracic spiracle enter the head, and at once break up into branches, too minute to be traced. There are minute tracheæ in the labium and antennæ, which expand at the base of the organs into small air sacs. The large space above and in front of the brain and pharyngeal muscles is entirely filled up with small air sacs, of which as many as twelve can be counted in some sections of the head. They are closely adherent to the epicranium and to the brain, and are most formidable obstacles in the dissection of the head. They have very tough and thick walls, and obviously can have little

or no function in the respiration of the insect. They serve as elastic cushions to protect the cerebral ganglia from the changes of intracranial tension during feeding, and have also a function, as will be seen later, in relation to the mechanism of feeding.

The *Thorax*.—The anterior thoracic spiracle is situated at the anterior end of the membraneous interval between the dorsal and lateral walls of the thorax. The posterior spiracle lies just in front of the halter. It should be noted that the spiracles are not orifices in the chitinous wall of the thorax, but are situated on the membrane joining adjacent sclerites. Each spiracle is a dumbbell-shaped slit, with a chitinous margin, on each side of which there is a row of short comb-like spines, to guard the orifice. The tracheæ which arise from them break up at once into numerous small branches distributed to the muscles and viscera. There are several small air sacs, resembling those of the head, around the thoracic ganglion.

The *Abdomen*.—There are seven spiracles, resembling those of the thorax, situated in the pleural membrane. The first one lies immediately behind the metathorax, the other being situated rather in front of their respective segments, and diminish in size from before backwards. The arrangement of the tracheæ within the abdomen is somewhat complex. The trachea from the first spiracle, after a short backward course, ends in a small air sac, which leads by a short connecting trachea to a second and larger air sac. These air sacs are entirely different to those of the head. Their walls are composed of a thin white opaque membrane, which when ruptured spreads out in water like a very thin paraffin section. It is very difficult to dissolve the air out of these vesicles, and sections of this part of the abdomen are difficult to prepare. Four small tracheæ arise from the second air sac. The first runs inwards, and breaks up at once into fine filaments for the supply of the adjacent fat body; the second trachea communicates with the second spiracle; the third runs along the dorsal wall, ventral to the heart, communicating with its fellow of the opposite side. The fourth and largest of these tracheæ runs directly backwards to the end of the abdomen as the main lateral trachea. This gives off six dorsal branches, which communicate with those of the other side, ventral to the heart, and many small branches to the viscera and to the ventral wall of the abdomen, and receives communicating branches from the third to the seventh tracheæ. Each trachea as it passes inwards from its spiracle gives off a number of small twigs to the surrounding parts; the fourth trachea supplies most of the mid-gut; and the fifth, which is of considerable size, constitutes the main supply of the ovary, which it enters along its posterior border.

III.—The Muscles of the Head.

The muscles associated with the mouth parts have been elaborately described and figured by Meinert (11) and Hansen (12), in Tabanus, and some of Meinert's

figures are to be found in most text books on Entomology. The arrangement of the parts in Hæmatopota does not differ materially from that described in Tabanus, but since the works of the above authors are in Danish, and are not readily accessible, an account of the parts will be given here. It will be necessary to go into considerable detail in order to facilitate the subsequent description of the mechanism of feeding. The muscles were studied by dissection and serial sections taken at various planes.

Labial Muscles.—The intrinsic muscles acting on the labellæ have already been described. There is also a pair of small retractor muscles, which arise from the tubercles at the base of the intracranial tunnels, and are inserted into the cornua of the labium.

Mandibular Muscles.—There are two adductor muscles attached to the inner cornua of the mandible. The internal of these, the adductor rectus, arises from the side of the trabecular membrane and from the intracranial tunnel. The oblique adductor arises from the floor of the head cavity, near the posterior border. The abductor muscle arises near the oblique adductor, and is inserted in the external cornu. It has a long tendon.

The *Maxillary Muscles* are also three in number. The adductor rectus arises from the inner side of the trabecular membrane, in common with the corresponding mandibular muscle, and the oblique adductor arises above and behind the oblique mandibular muscle. The two adductors run almost directly in the line of the maxilla, and are inserted into the lower end of the stipes. The abductor muscle of the maxilla arises from the gena, external to the anterior orifice of the intracranial tunnel, and runs upwards and backwards to the upper end of the stipes.

The *Depressor Labri* lies between the two lateral halves of the dilator muscle of the pharynx. It arises from the internal surface of the clypeus, and after a short course downwards and backwards is inserted into the tongue-shaped upper end of the labrum.

The *Muscles of the Pharynx.*—The *dilator* of the pharynx is the largest muscle in the head. It passes from the sides of the clypeus to the anterior plate of the pharynx, and encloses the depressor labri. It should be noted that the line of action of this muscle is not directly forwards, but forwards and outwards.

The *Retractor Muscles* of the pharynx arise from the epicranium between the eyes, just above the large pigment spots. They are of small size, and have long tendons, which are inserted into the cornua of the pharynx.

Hansen describes in Tabanus a " laxator " muscle of the pharynx, passing from the clypeus to the upper end of the pharynx. I have not been able, in Hæmatopota, to distinguish this muscle from the dilator.

The *Protractor of the Pharynx* arises from the inner sides of the trabecular membrane, and passes upwards and forwards to the cornua of the pharynx. It is short and stout, and has no tendon.

Muscles of the Œsophagus.—The *Dilator* muscle corresponds to that of the pharynx. It is broad and fleshy, and lies in a vertical plane, being attached to the epicranium in front of the vertex, and to the whole of the upper surface of the chitinous plate of the first part of the œsophagus.

The *Lateral Dilators* of the *œsophagus* arise from the epicranium in the region of the antennal sockets and from the adjacent parts of the trabecular membrane. They run inwards and backwards and a little upwards, and are inserted without tendons into the down-turned edges of the œsophageal plate. These muscles are called " Compressors " by Hansen.

The *Sphincter Muscles* are composed of circular and oblique fibres, which support the membraneous wall of the first part of the œsophagus. There are two bands, separated by the cornua of the pharynx, which run transversely between the lateral edges of the chitinous part of the wall, that is, on the inferior surface of the œsophageal pouch. The posterior bundle contains many oblique fibres, and is larger than the anterior one. There is also a circular sphincter, attached to the cornua of the pharynx, which encircles the short duct between the pharyngeal and œsophageal pouches.

The *Retractors* of the œsophagus arise from the sides of the occipital foramen, and are attached to the second part of the œsophagus as it leaves the brain. There are two small bundles on each side, arising above and below the foramen.

The salivary reservoir is surrounded by a fan-shaped muscle, which is attached to the posterior plate of the pharynx. Hansen also figures a mesial muscle lying between the adjacent borders of the lateral halves of this muscle.

IV.—The Mechanism of Feeding.

The sucking of blood is accomplished, after the insertion of the proboscis, by the alternate dilatation and contraction of the pharyngeal and œsophageal pouches, and the whole structure of the head is adapted to this function. The anatomy of the parts, considered with due regard to general mechanical principles, and to the observed habits of the living fly, provides an explanation of the exact mechanism. The process may be considered in three stages, the insertion of the piercing parts, the sucking of the blood, and the passage of the blood onwards into the gut.

The insertion of the piercing parts is accomplished, not by a movement of the parts themselves, but by a forward thrust of the whole body of the fly. Since the

proboscis has only a slight inclination forwards from the perpendicular, it is necessary, in order to obtain the greatest mechanical advantage, that the proboscis should be brought more into line with the long axis of the body. This is accomplished by bending of the neck, and by the elevation of the fly on its hind legs; this manœuvre brings the convex end of the prothorax in contact with the concavity in the posterior surface of the head. While in this position the fly, taking a firm hold in the skin of the host by means of the large claws on the metatarsi, gives a series of short jerks forwards. The wound is made by the mandibles and maxillæ, both of which have firm attachment to the chitinous wall of the head. The epipharynx and hypopharynx take little or no part in this process, since the pharynx, with which they are continuous above, has only membraneous and muscular connections with the rest of the head, and there is no rigid line through which the pressure can act. Moreover, the epipharynx has a blunted tip, and the slender hypopharynx falls a little short of the other mouth parts.

The mandibles and maxillæ can perform lateral and to and fro movements, by which the wound is enlarged and kept open. The nature of the movement of their muscles is co-related in a remarkable manner with the nature of the armature, in each case. By the alternate contraction of its adductor and abductor muscles, the mandible rotates on its fixed point, the ginglymus, through a short arc, and at each contraction of the adductor muscles the saw-like edge is brought into play.

By similar alternate contractions of its muscles the maxilla is alternately bent and straightened, the movement taking place at the joint between the cardo and stipes, and in this way the rasps on the end of the blade are forced up and down in the wound. During the making of the wound, the pharynx, carrying with it the labrum-epipharynx and the hypopharynx, is retracted by contraction of the retractor muscles attached to its posterior cornua; this is facilitated by the retractor muscles of the labrum, which pulls upwards and forwards on that part of the upper end of the labrum which is not fused with the epipharynx. When the wound is made, the pharynx is thrust down by the contraction of the protractor muscles.

The second part of the feeding process is the dilation of the pharynx. This is accomplished by the contraction of the powerful dilator muscles, which pull the anterior plate forwards, and reduce its concavity.

At first sight it is a little difficult to understand why the pharynx is not drawn forwards as a whole, since there is no muscle or firm chitinous attachment to directly oppose the dilator muscles. This is prevented by the combined action of the protractors and retractors of the pharynx. When these two muscles act together, the vertical element in the force of each will be neutralised by the other, so that

the resultant pull, the protractor muscle being the larger, will be backwards. The lower end of the pharynx is meanwhile steadied by the clypeus, against which the labrum-epipharynx rests.

During the dilatation of the pharynx the sphincter muscles of the œsophagus are contracted; when the pharynx is full, they relax, and the blood is drawn from the pharynx to the sacular part of the œsophagus by the contraction of dilator muscles of the œsophagus. The sphincter muscles then again contract, and so drive the blood backwards into the gut, the second part of the œsophagus being held taut by its retractor muscles. The pharynx now dilates again, and the process is repeated until the insect has had a full meal.

The intracranial tunnels have an important relation to the mechanism of feeding. They are nearly parallel to the dilators of the pharynx, which lie, in fact in the chamber formed by the trabecular plates arising from their upper surfaces.

The chitin in the region of the clypeus is very thin, and were it not that the intracranial tunnels support it and distribute the strain on to the thicker parts at the base of the skull, would be unable to resist the powerful dilators.

It will be noticed that the pharynx has no sphincter muscle to bring the two plates into apposition when the blood flows to the œsophagus, and that the muscles which close the œsophagus are very much smaller than the dilators. The collapse of these chambers is usually attributed, in the mosquito, to the elastic recoil of the plates, elasticity being assumed as a property of this variety of chitin. Whether this be the case or not, it is highly probable that the air sacs in the head play an important part in the mechanism. When the pharynx is filled with blood, the sphincter between it and the œsophagus being contracted, the intracranial pressure must necessarily be increased. This will result in a compression of the air in the sacs, and, when the sphincters are again relaxed, the positive pressure will be used up in bringing the plates once more into contact. Increased pressure is to a certain extent allowed for by the palatal membrane.

The mechanism of the salivary apparatus is simple. The saliva is forced from the glands into the reservoir by the contraction of the thoracic muscles in which they lie, and is ejected from the reservoir by the contraction of its fan-shaped muscle.

V.—The Reproductive System.

This consists of paired ovaries and accessory glands, an oviduct, a genitial bursa, and three spermathecæ.

The *Ovaries* lie in the last three or four segments; unlike the mosquitos', they do not, even when the ova are ripe, produce any considerable distension of

the abdomen. They are white pear-shaped bodies, in which the separate ova can be readily distinguished. The apex of each is produced forwards as a delicate filament, which can be traced to the fat body on the dorsal wall of the abdomen in the second segment. The ovary is invested by a few scattered muscle fibres, continuous with the oviduct and with the apical filament. The rich tracheal supply enters along the rounded posterior border. Each ovary consists of 54 short ovarian tubes, each of which contains a single large oval ovum. Above the ovum there is a small conical cap of undifferentiated cells, the apex of which runs forwards to join the apical filament. Below the ova, the tubes enter a common duct, which runs in the outer and posterior borders of the organ, and which is continuous with the oviduct. This duct is well seen in the transverse sections of the ovary, in which it appears as a narrow slit, extending about one-fourth the circumference of the organ. The *oviducts* are short, and unite to form a common duct, opening into the genital bursa. They are composed of muscle fibres arranged in circular and longitudinal layers. The fibres are attached behind to the chitinous frame work of the genital bursa ; above they are continuous with the thin wall of the common duct of the ovarian tubes.

The *Accessory glands* lie between the ovaries, extending as far forwards as the midgut. They are long and tubular, and open into the genital bursa by short constricted necks. In fresh dissections they are a dirty yellow colour, owing to the granular secretion which they contain. The walls of the gland are thrown into four or five longitudinal folds. They are composed of short cylindrical cells, on a thin basement membrane.

The *Spermathecæ* are three long chitinous tubes, bent sharply on themselves about the middle, so that the proximal and distal halves lie parallel to one another. They open by a very short common duct into the gential bursa. The blind end of the tube is dilated and oval, and is bound down to the genital bursa by a few fine filaments. The chitinous wall of the tube is thickest in the distal half ; from the bend it thins gradually and can only be distinguished with some difficulty towards the base. It is striated transversely, and appears to consist of a large number of circular fibres of chitin. It is covered externally by a layer of small round cells, external to which, in the proximal part of the tube, where the chitin is thin, there are a few bundles of muscle fibres. At the base of each spermatheca, just above the point at which the three unite to form a common duct, there is a remarkable funnel like structure developed in the wall of the tube. This consists of a central hollow cylinder of thick chitin, slightly curved, and tapering to a point below. This is enclosed in a series of thin transparent rings of chitin, somewhat loosely arranged, and apparently spiral. They project a considerable distance from the surface of the cylinder, and support the layer of round cells. In front of the tube, and slightly separated from it, there is a short but wide flange of chitin,

shaped like a short funnel. The whole structure closely resembles a short, hollow and slightly bent screw. (Plate VII, Fig. 34.)

The *Genital Bursa* is the continuation of the common oviduct, and into it open the accessory glands and the spermathecæ. Its wall is supported by an incomplete framework of delicate chitin, consisting of one transverse and two lateral plates. The lateral plates are oblong, and concave upwards, and lie mainly in the horizontal plane, but are inclined towards one another. The transverse plate lies in front of them, and is connected with the lateral plate on each side by a thick rib of chitin, which is continuous with its thickened anterior border, and with a ridge near the inner border of the lateral plate. The anterior plate is also concave, and the three together form a support for the lower wall of the bursa.

The posterior end of the bursa is partly closed in by two thick curved ridges of chitin, which arise from the lateral plates, and converge backwards and inwards towards one another. Each of these ridges has a row of peculiar spines (Plate XII, Fig. 26), which project inwards and so further close in the aperture. This arrangement constitutes a sort of valve, and suggests an explanation of the extraordinary scarcity of the males of the species late in the season. On anatomical grounds it is unlikely that the males will be able to disengage unharmed after copulation, and it may be that as in the case of the bee (19), copulation is fatal to the male fly.

VI.—The Nervous System.

This consists of a compound ganglion in the head, thoracic and abdominal ganglia, and their connectives and nerves. It shows a moderate degree of concentration. The optic lobes, cerebral ganglia, and the sub-œsophageal ganglia, are fused into one mass, which lies in the posterior part of the head, and envelopes the second part of the œsophagus. It is shaped like a short stout cylinder, the transverse diameter being about four times the width. The anterior surface is indented as approximately equal fourths, indicating the lines of fusion of the optic lobes and central bodies ; the posterior surface is similarly indented in thirds, the nerve cord which passes through the neck arising, by two branches from the middle third. The antennal nerves arise from the outer sides of the central lobes, and pass directly forwards to the antennæ, between the air sacs. Three small nerves arise on each side from the inferior surface of the central body, and break up above to be distributed to the adjacent muscles. One small filament can be traced in serial sections to the labium. The optic nerves arise from the whole outer surfaces of the optic lobe on each side, in a conical bundle, the fibres of which spread out forwards and inwards over the wide area occupied by the eyes.

The envelopment of the œsophagus by the brain is well demonstrated in serial sections parallel to the proboscis. The first part of the œsophagus lies at a slightly

higher level than the brain, so that the intra-cerebral portion enters the brain towards its upper surface, and passes through with a downward inclination, emerging near the lower surface, just above the nerve cord. The parts are so much fused that the relation of the ganglia to the œsophagus, found in more primitive insects, is lost.

The nerve cord lies in the head above the salivary duct. As the duct divides the nerve passes between the divisions and comes to lie on the ventral wall of the prothorax. It here gives off two small nerves, probably recurrent, the course of which has not been traced.

The *Thoracic Ganglion* lies in the prothorax. It is flattened from above downwards, and is shaped somewhat like a heraldic shield. It consists of three fused ganglia, the distinction between which can be readily made out in suitably stained preparations. There are two small accessory lobes, attached to the external angles of the anterior border, and projecting from the under surface. Seven nerves emerge from each side of the ganglion, and are distributed to the thoracic muscles. Two small bundles emerge from the region of the accessory lobes, and one large trunk from the posterior border of each of the constituent ganglia. The middle one of these is much the largest, and emerges in two parts. The seventh nerve is a small filament lying just external to the emerging commissure at the posterior end. It may, perhaps, indicate the fusion of an abdominal ganglion with the thoracic ganglia.

The *Abdominal Ganglia* are connected with the thoracic by a comparatively long cord. There are five discrete ganglia, of which the largest represent two fused together. The first, second, and third are small round masses, separated from one another and from the fourth by short cords. The fourth and fifth one partially fused; the fifth is larger and more oval than the rest, and, as in the case of the thoracic ganglion, its constituent parts are easily recognised by suitable staining. A pair of delicate nerves emerges from each ganglion, two pairs coming from the fifth. They are of considerable length and appear to run to the lateral walls near the spiracles, but on account of their extremely small size it is difficult to be certain of their precise distribution.

VII.—The Heart and Fat Body.

The heart lies in the dorsal wall of the abdomen. It is a simple and extremely delicate tube, and is embedded in a mass of yellow pericardial cells, which are adherent to its wall. The aorta arises from its somewhat dilated anterior end, and arches upwards in contact with the dorsal wall of the thorax. It can be traced through the neck into the head, where it divides into two minute branches.

The Fat Body is distributed throughout the body in the usual manner. A large mass of it surrounds the mid-gut.

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Plate I.

Hæmatopota Pluvialis.

× 12

Plate II.

Fig. 1.—The Maxilla, with its palpus, × 55.

Fig. 2.—The tip of the Maxilla, showing the rasps. × 1000. about.

Fig. 3.—Transverse section through the labium, about the middle of the labellæ. 1. e p. labrum-epipharynx. hy. hypopharynx. i.p. internal chitinous plate, lining the groove. l. sl. g. labial salivary gland. p. st. m. pseudo-tracheal membrane. ch. p. the upper chitinous plate on the outer wall of the labella. p.f. a pocket-like indentation, which runs the whole length of the labella, between the posterior border and the pseudotracheal membrane. × 250.

Fig. 4.—The labial salivary gland cells × 1000. about. v., vacucle.

Fig. 5.—The tip of the mandible showing the serrations on its internal edge. × 1000. about.

Fig. 6.—The Labium, seen from the side. l. p. lower chitinous plate. s.p. upper do. m. membrane. st. stipes. c.d. cardines. s.c. scutum. c. sc. cornua of the scutum. × 45.

Fig. 7.—The labrum-epipharynx. ep. c. its groove. l. labrum. × 55.

Fig. 8.—The Hypopharynx. sl. d. salivary duct. slv. saliv. reservoir. × 55.

Fig. 9.—The Mandible. sr. serrated edge. M. the thickened base. ad. o. oblique adductor. adr. abductor rectus. abd. abductor. N. nerve. g. ginglymus.

Plate III.

Fig. 10.—The head from the front. e. eye. a. p. antennal plate. i. t. anterior aperture of the intracranial tunnel. g. gena. cl. clypeus. p. maxillary palp. × 24.

Fig. 11.—Salivary gland, transverse section. × 400.

Fig. 12.—Antenna. r. "rings" on the distal joint. × 55.

Fig. 13.—The base of the skull : (*vide* page 11) × 55. l. epi. p. labrum epipharynx. mx. maxilla. gl. galea. ms. stipes of maxilla. mxc. cardo of maxilla. mn. mandible. hy. hypopharynx. lb. labrum. sr. salivary reservoir. ph. pharynx. ph. c. the cornua of the pharynx, between which the first part of the œsophagus lies. mb. palatal membrane. lr. lateral rod. or. the fibres forming the lower boundary of the occipital foramen. or. the posterior arch of the foramen. oc. f. occipital foramen.

Plate IV.

Fig. 14.—The Prothorax from above. p. st. presternum. st. sternum. stl. sternellum. ms. mesosternum. epm. epimeron. eps. episternum. f. l. space for articulation of the foreleg. a. f. the anterior fibres of the antefurca. × 90.

Fig. 15.—The Mesofurca. × 90.

Fig. 16.—The Postfurca. lying on the metasternum. fe. femur. tr. trochanter. cx. coxa of the hind leg. mes. metasternum. mr. median ridge between the metasternum. p. f. postfurca. × 75.

Fig. 17.—The Muscles of the head : diagramatic. d. ph. dilator of the pharynx m. l. labral muscle. lb. labrum. m. p. lateral dilator of the œsophagus. c. p. the sphincter between the pharynx and œsophagus. cp. the anterior and posterior sphincters of the œsophagus p. p. the protactor or depressor of the pharynx. p. p. pharynx. œs. œs′. first and second part of the œsophagus. d. œs. dilator of the œsophagus. r. ph. retractor of the pharynx. se. r. salivary reservoir. sl. d. salivary duct. mcr. compressor. muscle of the salivary reservoir. X 33.

Fig. 18.—The tip of the Epipharynx. × 1000. about.

Plate V.

Fig. 19.—The thorax : the lateral wall is drawn from within, after removal of the muscles. pn. pronotum. ep. epimeron. ep.^{1} episternum. j^1. j^2. j^3. the three jugulares. s.^{1} presternum. s^2. the transverse band of the antefurca. s.^{3} sternum. s^4. sternellum. a. th. sp. anterior thoracic spiracle, lying in the membraneous interval between the dosal and lateral walls. p. s. c. the posterior end of the præscutum. sc. scutum. w. s. cl. wing sclerites. co. costa, r. radius. s. q. squama. m. s. mesosternum. cp.^{2} episternum. ep.^{3} ep.^{4} epimeron. c. p. coxal plate for articulation of middle leg. mt. meta tergon. mt. meta-pleuron. m. s. metasternum. p. th. s. posterior thoracic spiracle. m. ph. metaphragm. abt. dorsal plate of the first abdominal segment. × 20.

Fig. 20.—The respiratory system of the abdomen. 1-7. tracheæ from the spiracles. f. b. to fat body. d. a. Dorsal branches (7). m. g. to mid-gut. o. v. the ovary. × 20.

Fig. 21.—The nervous system. a. n. antennal nerves. op. l. optic lobe. c. m. commissure. th. g. thoracic ganglion. abg. abdominal ganglia. × 17.

Fig. 22.—The foot and meta-tarsus. ×. 75. cl. claw. pv. pulvillus.

Plate VI.

Fig. 23.—The Alimentary Canal. l. e. p. labrum epipharynx. hy. Hypopharynx. p. h. Pharynx. œs^1. œs″. 1st and 2nd parts of the œsophagus. slr. salivary reservoir. sld. salivary duct. slg. salivary gland. œs. d. the œsophageal diverticulum. p. v. Proventriculus. m. g. midgut. m. p. t. malpighian tubes. il. ileum. co. colon. re. rectum, showing three of the papillæ, × 20.

Fig. 24.—The Proventriculus, showing the development of the intracellular secretion. × 1000.

Fig. 25.—The Spermathecæ. sp. d. the funnel-like tubes at the proximal end of the spermathecæ. c. d. common duct. opening into the genital bursa. × 48.

Plate VII.

Fig. 26.—One of the spines from the genital bursa. × 1000.

Fig. 27.—The chitinous framework of the genital bursa. × 54.

Fig. 28.—The wall of the hind gut. × 600.

Fig. 29.—The dorsal sclerites lying beneath the seventh segment. 11. figures anal lobes. × 50.

Fig. 30.—The corresponding ventral sclerite. X 50.

Fig. 31.—Transverse section of proximal part of spermatheca. X 450.

Fig. 32.—Section through the spiral funnel at the base of the spermatheca. X 450.

Fig. 33.—Section through the distal end of the spermatheca. X 450.

Fig. 34.—The spiral funnel at the base of the spermatheca. X 400.

Fig. 35.—A villus of the mid-gut. X 600. tr. trachæ. bm. basement membrane. m. muscle.

Fig. 36.—The ovary. o. v. t. ovarian tubule. ov. d. ovarian duct. c. o. d. common ovarian duct. X 27.

PLATE I.

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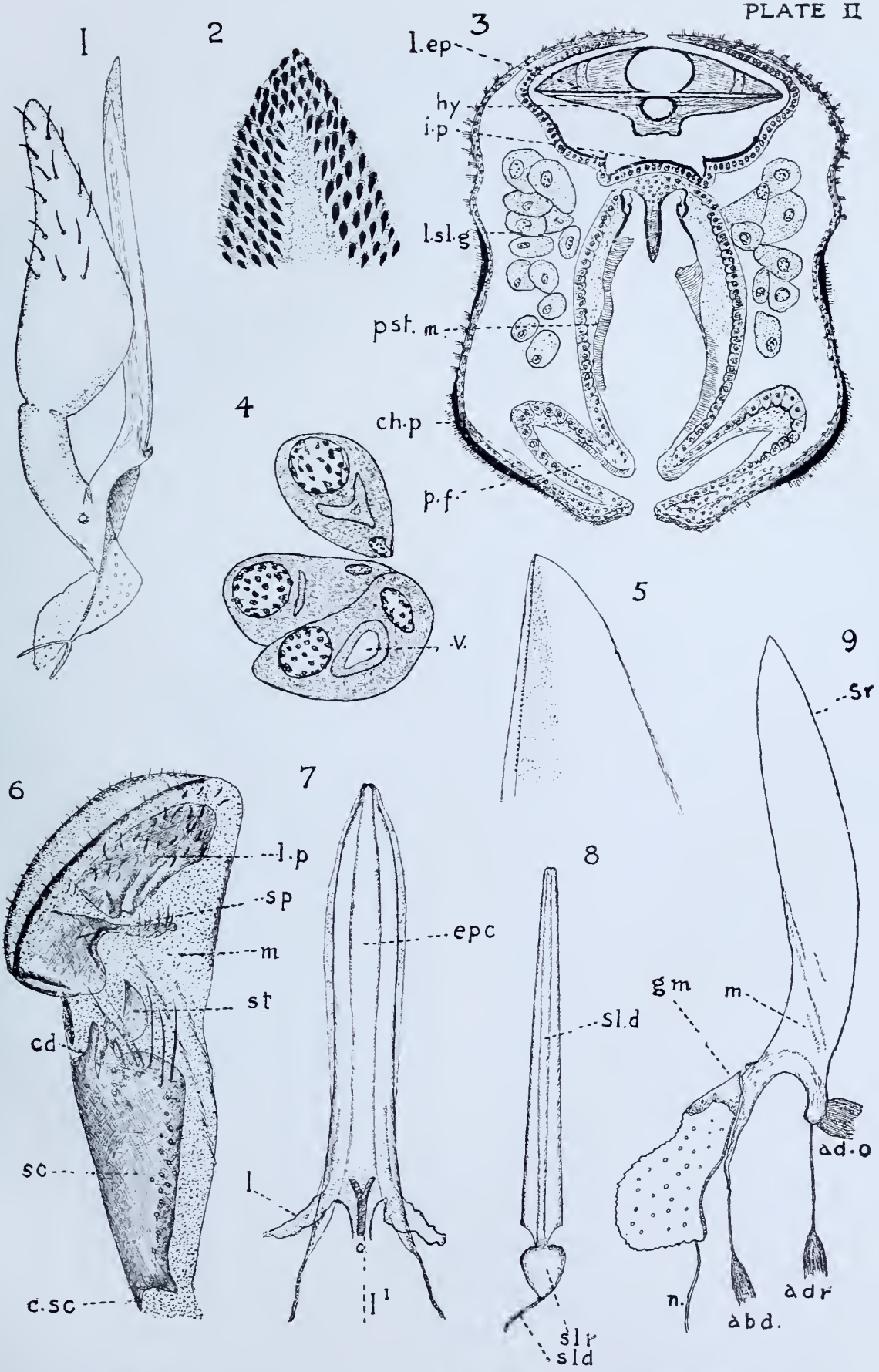
PLATE II



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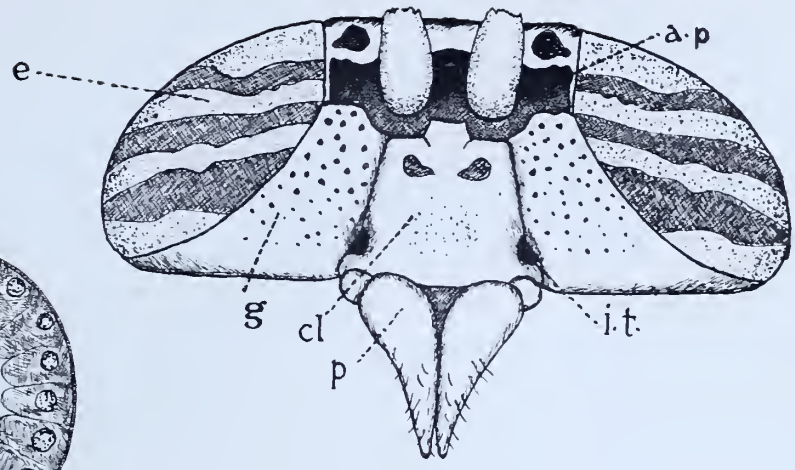

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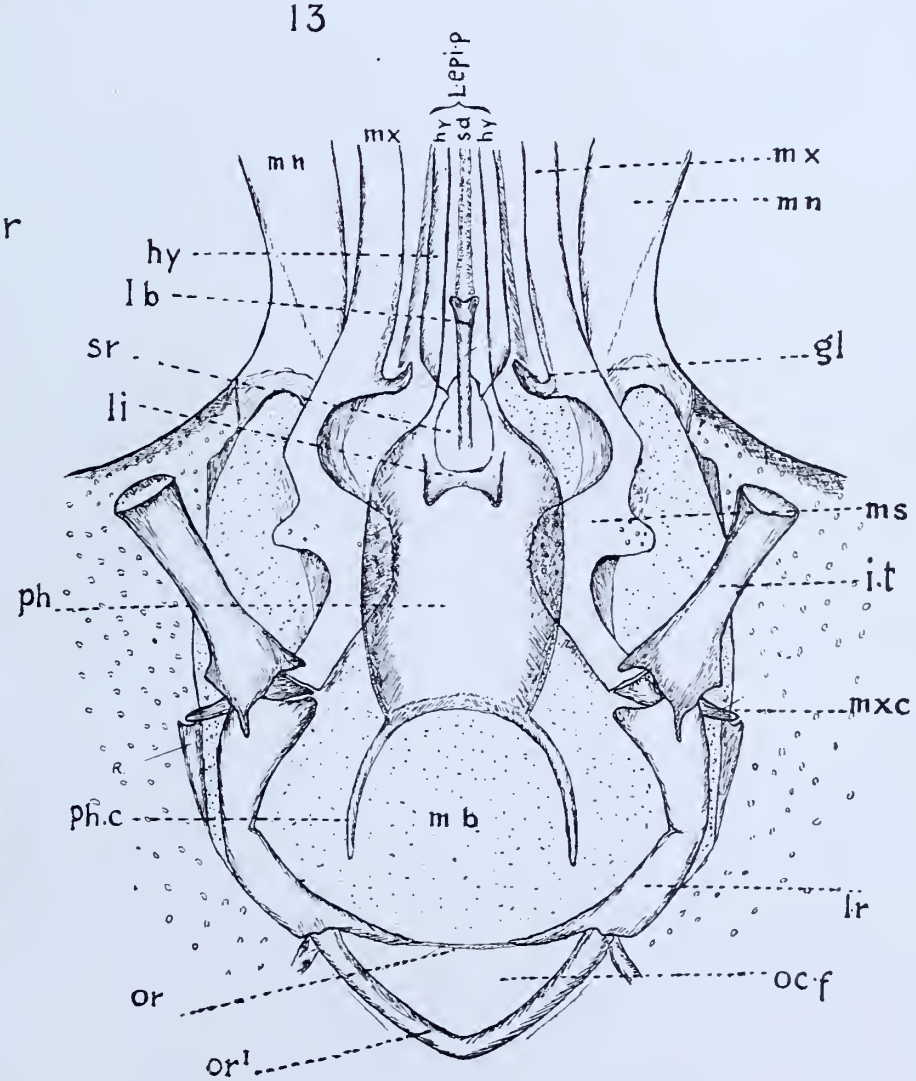

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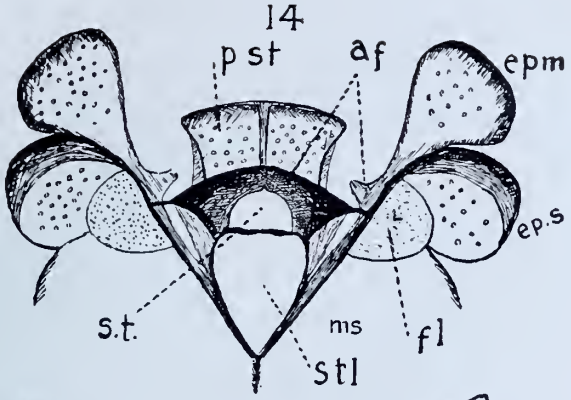
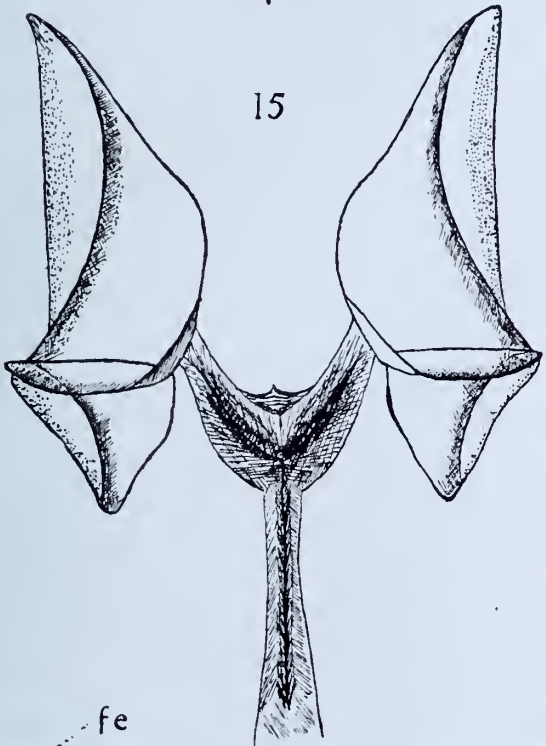
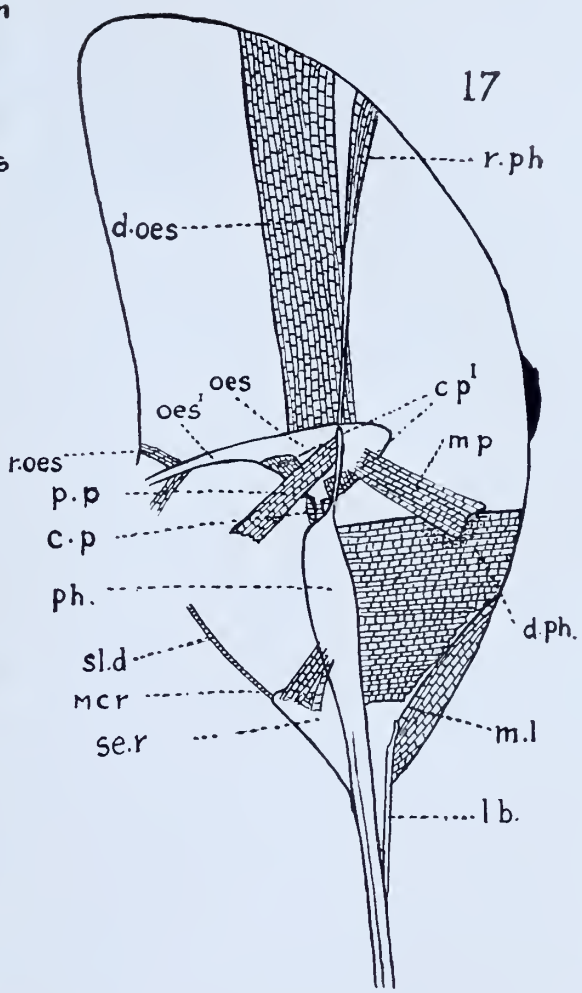
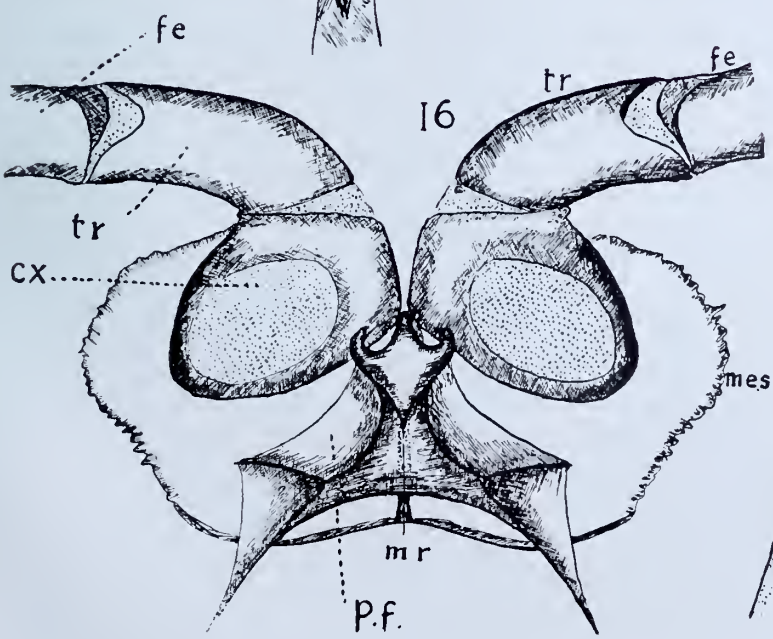
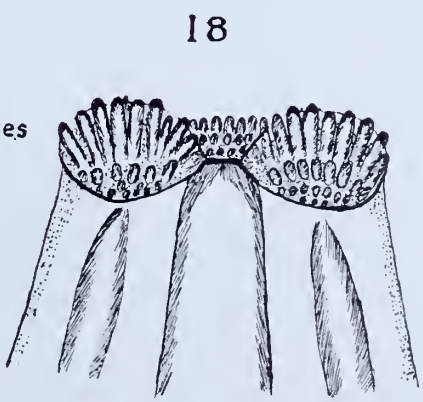
PLATE IV











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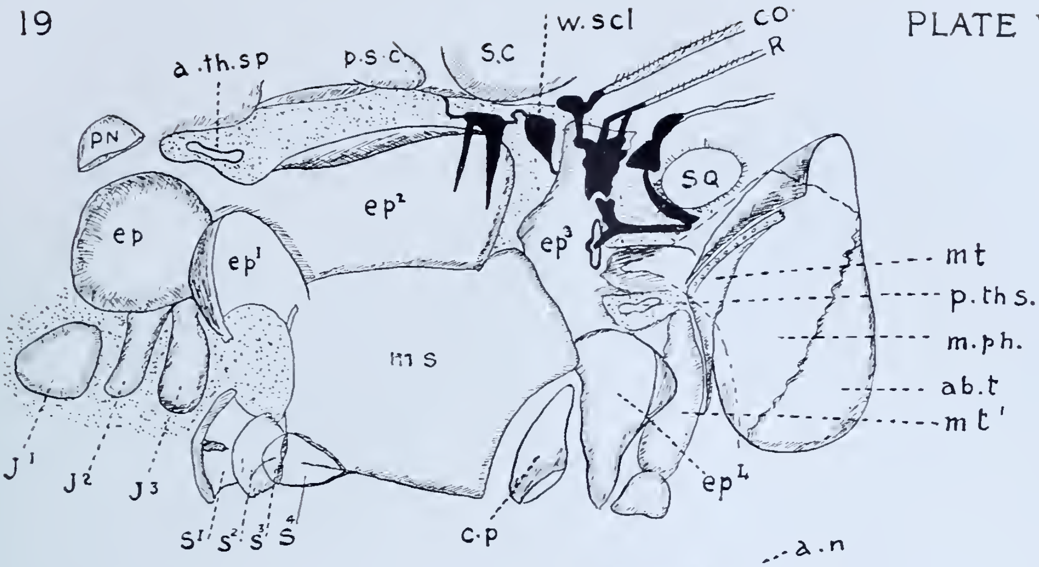

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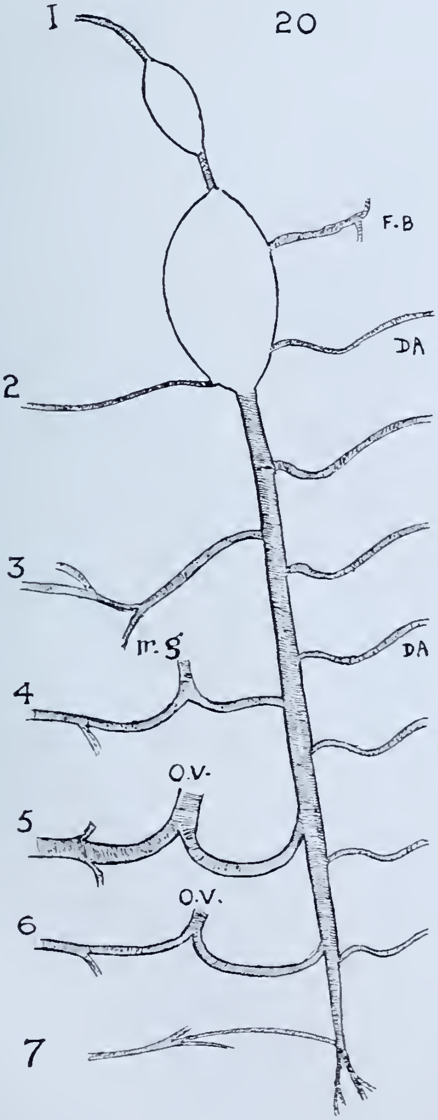

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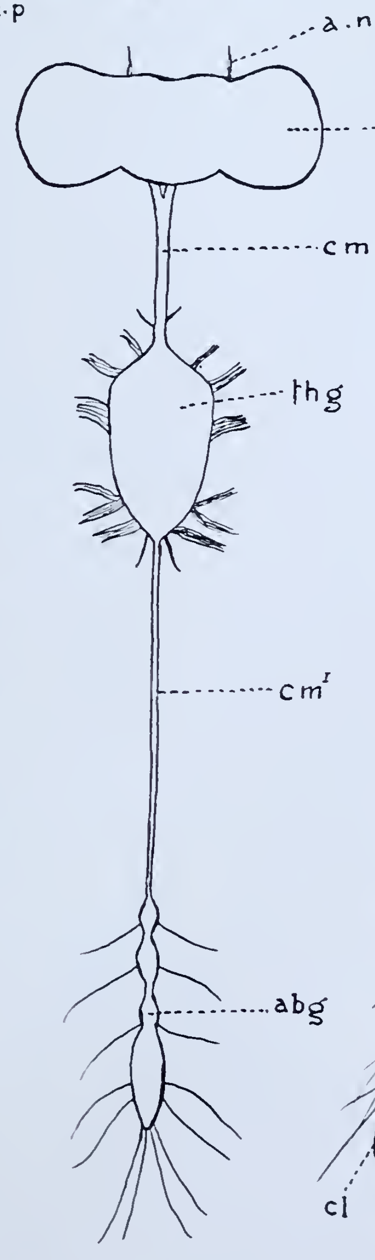

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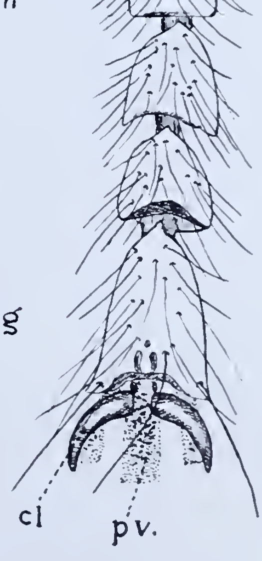

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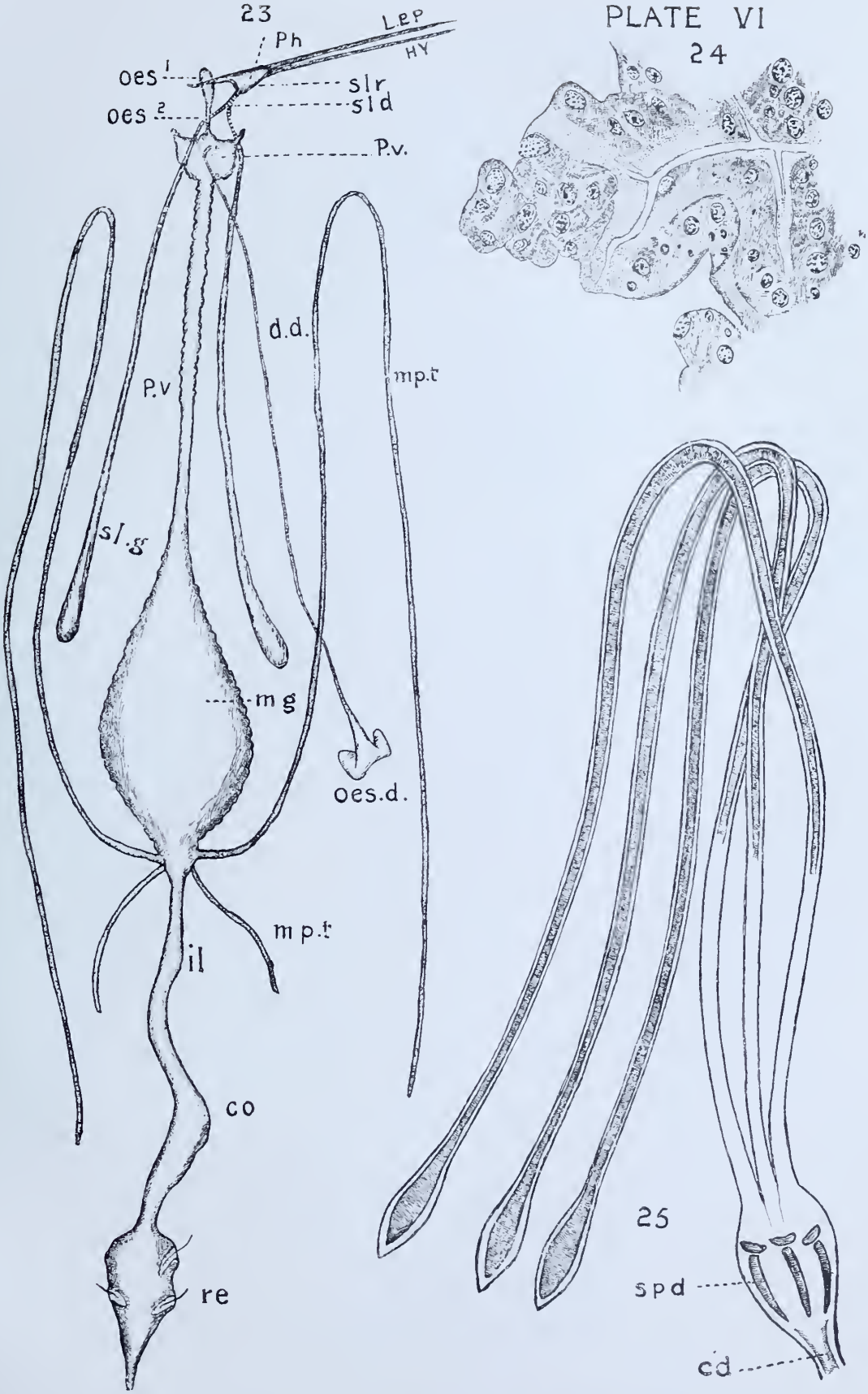

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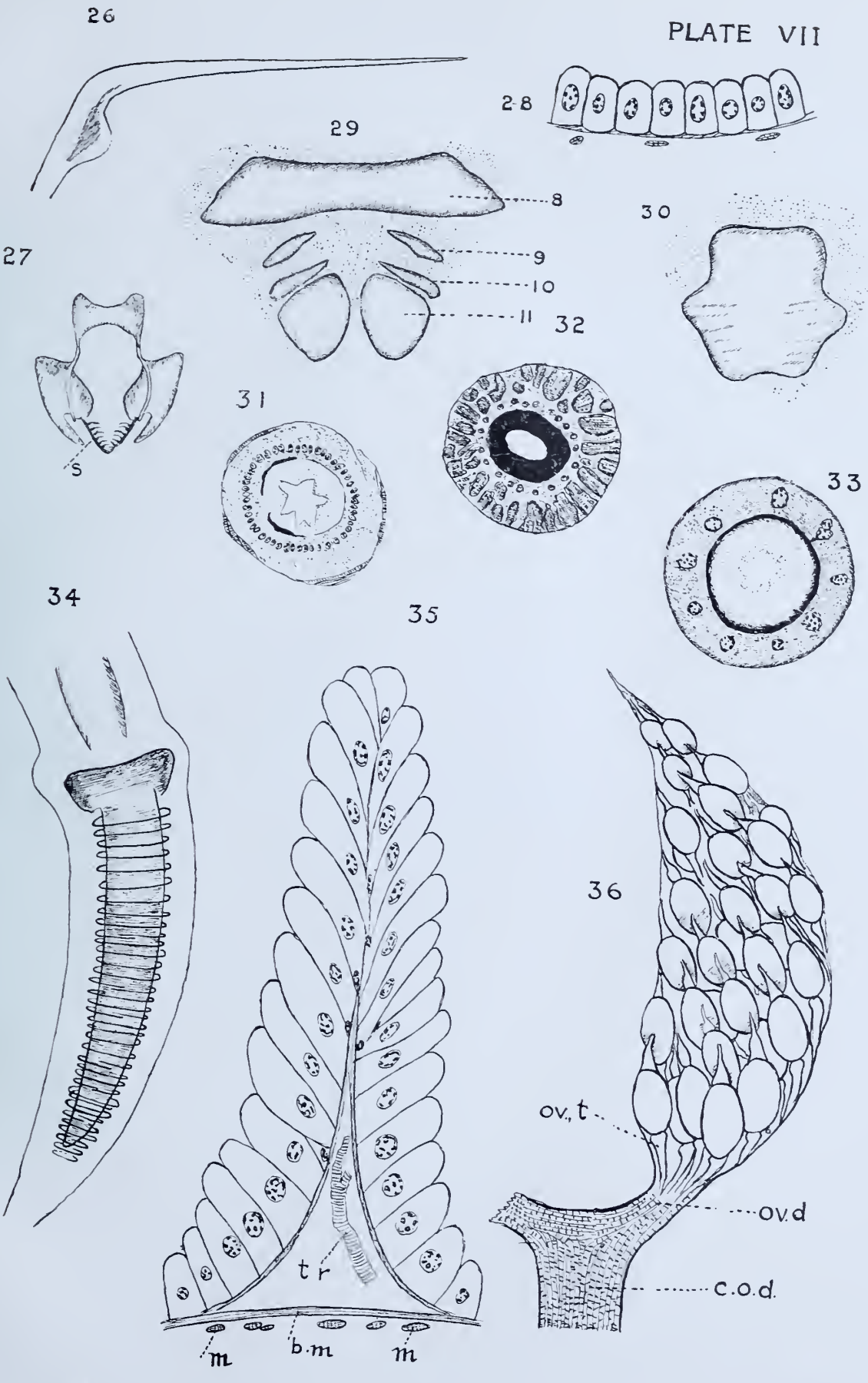

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